NRDL TRC-68-53

NUCLEAR RADIATION SHIELDING STUDIES
Report No. 8

MONTE CARLO CALCULATION OF GAMMA-RAY PENETRATION OF RIBBED SLABS

By
E. E. MORRIS

A FINAL REPORT OF AN INVESTIGATION CONDUCTED
under the sponsorship of
THE OFFICE OF CIVIL DEFENSE
under
Contract N0022866C0311
OCD Work Unit 1112C

UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

DECEMBER 1968

81

DISCLAIMER NOTICE

THIS DOCUMENT IS BEST QUALITY PRACTICABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

MONTE CARLO CALCULATION
OF GAMMA-RAY PENETRATION
OF RIBBED SLABS

by

E. E. Morris
University of Illinois
Nuclear Radiation Shielding Studies

Report No. 8
December 1968
NRDL TRC-68-53

for

Office of Civil Defense
Office of the Secretary of the Army
Washington, D. C. 20310

through the

U. S. Naval Radiological Defense Laboratory
San Francisco, California 94135

Contract N0022866C0311; OCD Work Unit 1112C

Approved:

A. B. Chilton

A. B. Chilton
Principal Investigator

OCD Review Notice

ACKNOWLEDGEMENTS

Appreciation is expressed to Dr. A. B. Chilton for numerous suggestions regarding this work and to Mr. Lynn Barry for his editorial assistance in preparing the report.

ABSTRACT

Data are given in the form of attenuation factors for the exposure due to gamma radiation transmitted by a ribbed slab. The ribbed slab is made of concrete and is similar to one which has been used in experimental studies conducted at the University of Illinois. The source radiation was assumed to be that of Co-60 with source spectrum degradation due to the self-shielding of the source. Four angles of incidence, 0°, 45°, 60°, and 75°, were considered. In addition, the effect of a beam of radiation incident with directions diverging 2.5° on either side of 45° was studied in a rather crude fashion. Attenuation factors for 1.25 MeV gamma radiation incident normally on a simulated wood floor are included in an appendix.

TABLE OF CONTENTS

I. INTRODUCTION

The primary purpose of the calculations described in this report is to provide a set of theoretical data to be compared with results obtained in ribbed-slab shielding experiments which have been conducted at the University of Illinois. Preliminary comparison between experimental results and the data of this report indicates that satisfactory agreement can be expected. However, the analysis of the experimental data is not yet complete and detailed comparisons will be made in a later report.

The basic geometry which was considered is a plane, horizontal, homogeneous slab, with ribs constructed from the same material resting parallel to each other on the slab. A plane, monodirectional source of gamma radiation is assumed to be incident on the side of the slab opposite the ribs. Detectors are placed at various distances from the ribbed side of the slab and at various horizontal positions relative to the ribs. The responses of these detectors are expressed as attenuation factors. In this report, the attenuation factor for a given detector is defined as the ratio of the exposure received by the detector when the ribbed slab is present to the exposure it would receive when the ribbed slab is absent.

The second section of this report describes the Monte Carlo calculation of the contribution of scattered radiation to the attenuation factor and an analytical calculation of the contribution of uncollided radiation. In the third section, data comparable to the experimental data mentioned above are presented and discussed. Attenuation factors for radiation incident normally on a simulated wood floor are tabulated in Appendix A. The computer program which was used for the calculations is described in Appendix B.

II. CALCULATION OF ATTENUATION FACTORS

A. General Description of the Problem

Figure 1 shows a cross-section view of a ribbed slab. The ribs are infinitely long and perpendicular to the plane of the figure. The

z-axis is perpendicular to the ribs. The y-axis (not shown in Figure 1) is parallel to the ribs. Photon directions are specified by direction cosines, u_x, u_y, and u_z, relative to the coordinate axes. The initial photon direction is defined by the cosine of the polar angle θ_o and the azimuthal angle φ_o so that the initial direction cosines are given by

$$u_{xo} = \sin\theta_o \cos\varphi_o \quad ,$$
$$u_{yo} = \sin\theta_o \sin\varphi_o \quad ,$$
$$u_{zo} = \cos\theta_o \quad .$$

The attenuation factor is computed as a function of detector height above the slab and the horizontal position of the detector relative to the ribs. It is designated by $A_f(\theta_o,H,X)$ where,

$$H = \frac{z_d - z_s}{2x_r} \quad ,$$

and

$$X = \frac{x + x_r}{2x_r} \quad .$$

Here, (x, z_d) are the coordinates of the detector position, z_s is the slab thickness not including the ribs, and x_r is half the separation distance between rib centers (see Figure 1). Because the rib structure extends to $x = \pm \infty$, and the ribs are infinitely long, $A_f(\theta_o,H,X)$ is a periodic function of X . Thus, it was calculated only for $0 \le X \le 1$. The dependence of $A_f(\theta_o,H,X)$ on φ_o, the slab material, and the rib configurations has not been indicated explicitly because the calculations in this report were done only for $\varphi_o = 0^o$ and for a single slab material and slab-rib geometry.

The attenuation factors $A_f(\theta_o,H,X)$ were computed in two steps. The contribution due to scattered radiation was calculated by Monte Carlo methods and the contribution of unscattered radiation was determined analytically. Thus, the attenuation factor may be written as the sum of two terms,

$$A_f(\theta_o,H,X) = A_f^s(\theta_o,H,X) + A_f^o(\theta_o,H,X)$$

where the superscript s refers to scattered radiation and o refers to unscattered radiation.

B. Monte Carlo Calculation for Scattered Radiation

Source points were selected by dividing the interval $-x_r \le x \le x_r$ into a certain number of increments and choosing the midpoint of each increment as the starting point. An identical number of histories originated at each point. The initial photon direction was the same for each history. The source energy spectrum was assumed to consist of N discrete energies E_n each having probability w_n. Thus,

$$\sum_{n=1}^{N} w_n = 1 \quad .$$

At the beginning of each history, one of the energies E_n was selected at random according to the probability function $P(E_n) = w_n$.

Only photon trajectories within the region $-x_r \le x \le x_r$ (see Figure 1) were considered. If the photon left this region by crossing the boundary $x = x_r$ $(x = -x_r)$, it was treated as a photon entering the region at $x = -x_r$ $(x = x_r)$. Each time the position for an interaction was determined, the coordinates (x,z) of the interaction point were checked to see if $-x_s < x < x_s$ <u>and</u> $z_s < z < z_r$. If this was found to be the case, the photon was moved along its trajectory until it re-entered the ribbed slab or until z became equal to z_r. If the photon re-entered the slab, a position for a new interaction point was selected.

The Monte Carlo calculation was designed to accommodate any photon energy below 10 MeV. Thus, the photoelectric effect, Compton scattering, and pair production were taken into account. At the beginning of each photon history, the photon was assigned a statistical weight of unity. Each time the photon had a collision, this statistical weight was multiplied by the probability that the interaction was not a photoelectric absorption. Then either a Compton-scattering interaction or a pair-production interaction was selected using the appropriate probabilities for these interactions, given that photo-

electric absorption did not occur. A new photon energy and direction were determined and the history continued. If a pair-production interaction was selected, the statistical weight was doubled, the new photon energy was set equal to 0.511 MeV, and the new photon direction was sampled from an isotropic distribution. If a Compton-scattering interaction was selected, the new photon energy and direction were sampled from the Klein-Nishina distribution for unpolarized photons. A photon history was terminated when the photon was transmitted or reflected by the slab, or when its energy dropped below a specified cutoff energy.

The interval $-x_r \le x \le x_r$ was divided into a number of detection intervals as illustrated in Figure 1. When a photon was transmitted by the slab, it crossed the detector plane $z = z_d$ by passing through one of these detection intervals. Scores for several detector planes were recorded simultaneously. The contribution to flux was estimated by dividing the statistical weight of the photon by the direction cosine u_z of the photon trajectory. To avoid the problem of the infinite variance of this flux estimator, a cutoff value for u_z was introduced as suggested by Clark[1]. For the data in this report, contributions to the flux were not recorded when the direction cosine u_z of the trajectory of the transmitted photon was less than 0.01. The error introduced by the use of this cutoff was much smaller than the statistical standard deviation of the final results. The average exposure was calculated for each detection interval and recorded as a function of the midpoint of the interval.

C. <u>Analytical Calculation for Uncollided Radiation</u>

Attenuation factors for the uncollided radiation were computed for a detector located at the midpoint of each detection interval used in the Monte Carlo calculation. This part of the calculation was done analytically. The main complication arose from the fact that the photon path length within the ribbed slab depended on both the height of the detector above the slab and the horizontal position of the detector with respect to the ribs. Nevertheless, the evaluation of this path length was straightforward although somewhat tedious and will not be described in detail.

Once the path length through the ribbed slab was evaluated the attenuation factor for uncollided radiation was calculated using

the formula,

$$A_f^o(\theta_o,H,X) = \frac{\sum_{n=1}^{N} w_n \mu_{en}(E_n) E_n \exp\{-\mu(E_n) t(\theta_o,H,X)\}}{\sum_{n=1}^{N} w_n \mu_{en}(E_n) E_n} ,$$

where μ_{en} is the linear energy absorption coefficient for air, μ is the total linear attenuation coefficient for the ribbed slab, and $t(\theta_o,H,X)$ is the path length within the ribbed slab.

III. ATTENUATION FACTORS FOR A PARTICULAR RIBBED-SLAB CONFIGURATION

A. Description of Input Data

In this section, calculated results are given for a ribbed slab whose dimensions correspond closely to the dimensions of the ribbed slab used in the experimental studies at the University of Illinois. Referring to the symbols as defined in Figure 1, some of the important dimensions were:

x_r = 6 1/8 inches
x_s = 4 1/8 inches
z_s = 4 inches
z_r = 10 inches .

The slab and ribs were assumed to be so-called NBS concrete with density 2.38 g/cm^3. The composition assumed for the concrete is listed in Table 1. The mass interaction coefficients used in the calculation are listed in Table 2. These are based on the atomic interaction coefficient data used by Hubbell and Berger[2]. Also listed in Table 2 are the mass energy absorption coefficients for air which were used in the calculation; the latter are also from Hubbell and Berger[2].

The spectrum of gamma radiation emitted by the experimental source was calculated in an earlier report[3]. When the source was in use, a 1/8 inch lead filter was placed over the end of the source and an auxiliary collimator was placed above the filter. Hence, the spectrum for the calculation was taken as the normalized spectrum for a 1/8 inch filter given in Table A2 of the report mentioned above[3]. This spectrum is illustrated in Figure 2.

TABLE 1

Composition assumed for the concrete used in the ribbed slab[2].

Element	Fraction by Weight
H	0.0056
O	0.4983
Na	0.0171
Mg	0.0024
Al	0.0456
Si	0.3158
S	0.0012
K	0.0192
Ca	0.0826
Fe	0.0122
Sum	1.0000

TABLE 2

Mass interaction coefficients for concrete. The density assumed for the concrete was $2.38 g/cm^3$. Also given are the mass energy absorption coefficients for air. Units for all the data are cm^2/g.

Energy (MeV)	Concrete			Air
	Compton Scattering Coefficient	Pair Production Coefficient	Total Attenuation Coefficient	Mass Energy Absorption Coefficient
0.010	0.193	0	26.5	4.61
0.015	0.190	0	8.01	1.27
0.020	0.186	0	3.45	0.511
0.030	0.180	0	1.12	0.148
0.040	0.174	0	0.559	0.0668
0.050	0.169	0	0.361	0.0406
0.060	0.164	0	0.273	0.0305
0.080	0.156	0	0.200	0.0243
0.100	0.148	0	0.170	0.0234
0.150	0.134	0	0.140	0.0250
0.200	0.122	0	0.125	0.0268
0.300	0.106	0	0.107	0.0287
0.400	0.0954	0	0.0957	0.0295
0.500	0.0871	0	0.0873	0.0296
0.600	0.0806	0	0.0807	0.0295
0.800	0.0708	0	0.0708	0.0289
1.000	0.0636	0	0.0637	0.0278
1.500	0.0517	0.000155	0.0518	0.0254
2.000	0.0441	0.000629	0.0447	0.0234
3.000	0.0347	0.00179	0.0365	0.0205
4.000	0.0290	0.00292	0.0319	0.0186
5.000	0.0250	0.00394	0.0290	0.0174
6.000	0.0221	0.00485	0.0270	0.0164
8.000	0.0181	0.00641	0.0245	0.0152
10.000	0.0154	0.00771	0.0231	0.0145

B. Results for a Perfectly Collimated Plane Source

Attenuation factors are given in Tables 3, 4, 5, and 6 for angles of incidence $\theta_o = 0^o, 45^o, 60^o$, and 75^o. The initial azimuthal angle φ_o was set equal to zero in all cases. In the tables, data are listed separately for $A_f^s(\theta_o,H,X)$ and $A_f(\theta_o,H,X)$. The percent statistical standard deviation for $A_f^s(\theta_o,H,X)$ was nearly constant as a function of H and X for a given value of θ_o; an average value for this quantity is given at the beginning of each table. The data for each of the angles $\theta_o = 0^o$ and 60^o are based on 100,000 histories. The data for each of the angles $\theta_o = 45^o$ and 75^o are based on 10,000 histories. The time required to process 100,000 histories on the IBM-7094 at the University of Illinois is about thirty minutes.

The attenuation factor $A_f^s(\theta_o,H,X)$ is plotted in Figures 3 and 4 for angles of incidence $\theta_o = 0^o$ and 60^o respectively. For both angles of incidence, the results show a strong dependence on the horizontal detector position X when H = 0.49, the height of the ribs. However, the data very rapidly lose their dependence on X as the detector height increases; for $H > 1$, the data are essentially independent of X.

The result of including the uncollided radiation in the attenuation factors for these angles of incidence is shown in Figures 5 and 6. As can be seen, in this case a dependence on X persists at all values of H. The amplitude of this dependence is, of course, a function of the angle of incidence. For the 60^o case, the main effect of changing H is to change the value of X where the attenuation factor $A_f(\theta_o,H,X)$ has its maximum.

Since, as illustrated in Figure 3 and 4, the attenuation factor for scattered radiation rapidly loses its dependence on X as H increases, it is of interest to examine the relationship between the average attenuation factor,

$$A_f^s(\theta_o) = \int_0^1 A_f^s(\theta_o,H,X)\,dX \quad ,$$

for the ribbed slab and the attenuation factor for a plane slab having the same average mass thickness. Monte Carlo calculations were

TABLE 3

ATTENUATION FACTORS FOR $\theta_0 =$ 0 DEGREES. THE FRACTIONAL STANDARD DEVIATION HAS AN AVERAGE VALUE OF ABOUT 3 PERCENT FOR THE ATTENUATION FACTORS DUE TO SCATTERED RADIATION ONLY. DATA IN THE TABLES SHOULD BE MULTIPLIED BY 0.1 TO GET THE CORRECT ATTENUATION FACTOR.

X \ H	.49	.98	1.47	1.96	2.94	3.92	4.90	5.88
	SCATTERED RADIATION							
.025	1.03	1.75	1.88	1.78	1.91	1.81	1.93	1.86
.075	1.11	1.68	1.79	1.75	1.78	1.88	1.81	1.92
.125	1.31	1.81	1.81	1.78	1.81	1.89	1.72	1.85
.175	1.76	1.75	1.89	1.88	1.85	1.77	1.85	1.84
.225	2.10	1.87	1.79	1.80	1.82	1.87	1.79	1.81
.275	2.18	1.77	1.90	1.86	1.83	1.79	1.81	1.81
.325	2.06	2.01	1.89	1.81	1.94	1.83	1.85	1.77
.375	2.16	1.89	1.81	1.85	1.80	1.81	1.83	1.83
.425	2.32	1.84	1.77	1.84	1.78	1.88	1.88	1.80
.475	2.25	1.88	1.88	1.76	1.86	1.90	1.83	1.85
.525	2.31	2.09	1.95	2.00	1.78	1.93	1.87	1.80
.575	2.26	1.89	1.81	1.85	1.83	1.91	1.83	1.71
.625	2.19	1.83	1.81	1.78	1.88	1.90	1.79	1.91
.675	2.17	1.94	1.83	1.91	1.93	1.88	1.83	1.86
.725	2.23	1.92	1.85	1.78	1.85	1.76	1.87	1.75
.775	1.93	1.79	1.86	1.85	1.78	1.77	1.88	1.82
.825	1.84	1.81	1.80	1.93	1.72	1.86	1.87	1.92
.875	1.31	1.75	1.78	1.72	1.84	1.79	1.87	1.80
.925	1.07	1.68	1.86	1.90	1.79	1.78	1.81	1.84
.975	1.09	1.76	1.77	1.87	1.91	1.69	1.80	1.94
	SCATTERED PLUS UNSCATTERED RADIATION							
.025	1.34	2.06	2.19	2.08	2.22	2.11	2.24	2.17
.075	1.42	1.99	2.09	2.06	2.08	2.18	2.11	2.22
.125	1.62	2.12	2.11	2.08	2.12	2.19	2.03	2.16
.175	4.23	4.21	4.35	4.34	4.31	4.23	4.31	4.30
.225	4.56	4.33	4.25	4.26	4.28	4.33	4.25	4.27
.275	4.64	4.23	4.36	4.32	4.29	4.25	4.27	4.27
.325	4.52	4.47	4.35	4.27	4.40	4.29	4.31	4.23
.375	4.62	4.35	4.27	4.31	4.26	4.27	4.29	4.30
.425	4.78	4.30	4.23	4.30	4.24	4.34	4.34	4.26
.475	4.71	4.34	4.34	4.22	4.32	4.36	4.29	4.31
.525	4.77	4.55	4.41	4.46	4.24	4.39	4.33	4.26
.575	4.72	4.35	4.27	4.31	4.29	4.37	4.29	4.17
.625	4.65	4.29	4.27	4.24	4.34	4.36	4.25	4.37
.675	4.63	4.40	4.29	4.37	4.39	4.35	4.29	4.32
.725	4.69	4.38	4.31	4.24	4.31	4.22	4.33	4.21
.775	4.39	4.25	4.32	4.31	4.24	4.23	4.34	4.28
.825	4.30	4.27	4.26	4.39	4.18	4.34	4.33	4.38
.875	1.62	2.06	2.09	2.02	2.15	2.09	2.17	2.10
.925	1.38	1.98	2.16	2.20	2.10	2.09	2.11	2.15
.975	1.40	2.07	2.07	2.18	2.22	1.99	2.11	2.25

TABLE 4

ATTENUATION FACTORS FOR θ_0 = 45 DEGREES. THE FRACTIONAL STANDARD DEVIATION HAS AN AVERAGE VALUE OF ABOUT 13 PERCENT FOR THE ATTENUATION FACTORS DUE TO SCATTERED RADIATION ONLY. DATA IN THE TABLES SHOULD BE MULTIPLIED BY 0.1 TO GET THE CORRECT ATTENUATION FACTOR.

X \ H	.49	.98	1.47	1.96	2.94	3.92	4.90	5.88
	SCATTERED RADIATION							
.025	.97	1.09	1.78	1.08	1.30	1.36	.96	1.11
.075	.77	1.24	1.28	1.18	1.43	1.38	1.27	1.38
.125	.61	1.33	1.25	1.30	1.06	1.09	1.21	1.07
.175	.84	1.24	1.03	1.09	.89	.99	1.18	1.02
.225	.85	1.02	1.04	1.23	1.01	1.46	1.53	1.19
.275	.91	1.39	1.21	1.27	1.16	1.34	1.26	1.51
.325	1.31	.99	1.01	1.66	.92	1.02	1.10	1.08
.375	1.17	1.01	1.24	1.18	1.08	1.06	.94	1.25
.425	1.43	1.43	1.03	1.35	1.34	1.43	1.10	.80
.475	1.41	1.15	1.24	1.06	1.21	1.40	1.18	1.45
.525	1.40	1.17	1.28	.95	1.02	1.30	1.12	1.06
.575	1.48	1.14	1.19	1.04	1.33	1.32	1.55	1.36
.625	1.66	1.19	1.23	1.31	1.06	1.16	1.22	1.26
.675	1.20	1.22	1.22	1.30	1.25	1.18	1.25	1.16
.725	1.46	1.45	1.12	1.40	1.06	1.10	1.23	1.44
.775	1.63	1.11	.97	1.17	1.34	1.06	1.03	1.16
.825	1.53	1.34	1.14	1.15	1.25	1.16	1.22	1.28
.875	1.22	1.20	1.30	.97	1.52	1.23	1.44	1.23
.925	1.15	1.14	1.20	1.16	1.45	1.16	1.30	1.09
.975	1.11	1.25	1.36	1.26	1.40	.90	1.04	1.21
	SCATTERED PLUS UNSCATTERED RADIATION							
.025	1.42	1.77	2.17	1.85	2.17	2.34	2.06	2.36
.075	1.10	2.15	1.57	2.21	2.60	2.70	2.65	2.76
.125	.86	2.57	1.47	2.69	2.44	2.47	2.59	2.45
.175	1.03	2.62	1.23	2.47	2.27	2.37	2.57	2.40
.225	1.05	2.40	1.23	2.61	2.39	2.84	2.91	2.57
.275	1.10	2.78	1.41	2.65	2.54	2.65	2.43	2.54
.325	1.50	2.37	1.22	2.90	2.02	1.99	1.96	1.84
.375	1.43	2.04	1.53	2.09	1.89	1.78	1.58	1.82
.425	1.78	2.19	1.43	2.02	1.94	1.96	1.57	1.22
.475	1.88	1.72	1.77	1.56	1.65	1.79	1.53	1.76
.525	2.04	1.59	2.00	1.32	1.35	1.59	1.38	1.29
.575	2.35	1.45	2.16	1.31	1.57	1.53	1.74	1.55
.625	2.82	1.42	2.55	1.51	1.26	1.36	1.41	1.45
.675	2.58	1.41	2.60	1.50	1.45	1.37	1.44	1.36
.725	2.84	1.65	2.51	1.59	1.26	1.29	1.42	1.65
.775	3.01	1.30	2.35	1.37	1.54	1.28	1.27	1.44
.825	2.91	1.54	2.46	1.39	1.51	1.46	1.56	1.65
.875	2.32	1.48	2.28	1.28	1.87	1.63	1.89	1.73
.925	1.96	1.52	1.92	1.58	1.93	1.70	1.90	1.78
.975	1.71	1.76	1.90	1.83	2.04	1.62	1.86	2.13

TABLE 5

ATTENUATION FACTORS FOR θ_0 = 60 DEGREES. THE FRACTIONAL STANDARD DEVIATION HAS AN AVERAGE VALUE OF ABOUT 5 PERCENT FOR THE ATTENUATION FACTORS DUE TO SCATTERED RADIATION ONLY. DATA IN THE TABLES SHOULD BE MULTIPLIED BY 0.1 TO GET THE CORRECT ATTENUATION FACTOR.

X \ H	.49	.98	1.47	1.96	2.94	3.92	4.90	5.88
				SCATTERED RADIATION				
.025	.44	.72	.68	.71	.68	.66	.60	.66
.075	.42	.63	.69	.64	.66	.63	.60	.64
.125	.38	.60	.61	.63	.64	.65	.61	.66
.175	.42	.67	.63	.65	.62	.66	.67	.64
.225	.53	.70	.61	.67	.65	.68	.65	.60
.275	.53	.62	.66	.61	.63	.63	.65	.64
.325	.59	.63	.68	.63	.64	.63	.63	.66
.375	.61	.64	.58	.61	.62	.64	.64	.62
.425	.73	.63	.63	.61	.60	.60	.60	.61
.475	.69	.59	.64	.67	.69	.63	.63	.63
.525	.81	.60	.61	.68	.62	.67	.65	.60
.575	.78	.67	.65	.60	.59	.61	.69	.68
.625	.78	.65	.61	.60	.70	.62	.61	.58
.675	.80	.63	.65	.64	.62	.63	.65	.70
.725	.82	.60	.59	.65	.61	.59	.66	.67
.775	.87	.62	.66	.68	.65	.70	.65	.63
.825	.84	.64	.65	.65	.61	.64	.58	.59
.875	.67	.67	.60	.58	.65	.62	.65	.68
.925	.59	.66	.66	.63	.66	.65	.69	.62
.975	.50	.64	.71	.65	.66	.67	.69	.69
			SCATTERED PLUS UNSCATTERED RADIATION					
.025	.68	.85	.81	.83	.88	.84	.72	.79
.075	.61	.75	.81	.77	.91	.77	.72	.80
.125	.53	.72	.74	.75	.90	.77	.73	.87
.175	.55	.80	.75	.78	.88	.78	.79	.90
.225	.56	.82	.74	.80	.91	.80	.78	.86
.275	.65	.75	.78	.77	.86	.76	.78	.90
.325	.72	.76	.80	.83	.82	.75	.76	.92
.375	.73	.76	.71	.86	.76	.76	.81	.85
.425	.85	.75	.78	.87	.73	.72	.81	.79
.475	.82	.71	.83	.93	.82	.75	.89	.76
.525	.93	.73	.86	.94	.74	.80	.91	.72
.575	.91	.82	.91	.84	.71	.73	.95	.80
.625	.90	.84	.87	.79	.83	.75	.87	.71
.675	.93	.87	.91	.79	.74	.79	.87	.82
.725	.97	.86	.83	.77	.74	.79	.84	.79
.775	1.06	.88	.85	.80	.77	.96	.79	.76
.825	1.09	.90	.80	.77	.74	.90	.70	.72
.875	.93	.91	.72	.70	.77	.88	.77	.81
.925	.85	.85	.79	.75	.78	.91	.82	.74
.975	.76	.79	.84	.77	.62	.90	.81	.81

TABLE 6

ATTENUATION FACTORS FOR θ_0= 75 DEGREES. THE FRACTIONAL STANDARD DEVIATION HAS AN AVERAGE VALUE OF ABOUT 18 PERCENT FOR THE ATTENUATION FACTORS DUE TO SCATTERED RADIATION ONLY. DATA IN THE TABLES SHOULD BE MULTIPLIED BY 0.1 TO GET THE CORRECT ATTENUATION FACTOR.

X \ H	.49	.98	1.47	1.96	2.94	3.92	4.90	5.88
				SCATTERED RADIATION				
.025	.08	.16	.21	.13	.20	.17	.18	.16
.075	.14	.16	.15	.14	.21	.18	.19	.16
.125	.07	.13	.20	.15	.15	.21	.19	.17
.175	.12	.13	.20	.17	.20	.13	.15	.16
.225	.14	.17	.13	.21	.20	.19	.14	.18
.275	.15	.15	.17	.20	.22	.14	.22	.17
.325	.19	.24	.27	.14	.13	.18	.19	.16
.375	.24	.24	.17	.19	.17	.18	.16	.22
.425	.18	.18	.18	.17	.16	.14	.14	.20
.475	.16	.17	.18	.15	.14	.12	.20	.14
.525	.22	.17	.14	.18	.15	.19	.16	.23
.575	.28	.16	.14	.19	.20	.16	.20	.20
.625	.15	.24	.17	.17	.17	.19	.19	.18
.675	.30	.15	.16	.19	.19	.17	.16	.19
.725	.21	.13	.18	.21	.19	.16	.16	.19
.775	.27	.17	.20	.17	.14	.21	.14	.11
.825	.17	.19	.21	.15	.13	.20	.18	.21
.875	.19	.20	.14	.16	.16	.18	.17	.17
.925	.18	.18	.14	.16	.20	.21	.18	.15
.975	.08	.20	.17	.28	.22	.21	.21	.18
				SCATTERED PLUS UNSCATTERED RADIATION				
.025	.09	.16	.22	.14	.20	.18	.18	.16
.075	.14	.16	.15	.15	.21	.18	.19	.16
.125	.07	.14	.21	.15	.15	.21	.19	.18
.175	.12	.13	.20	.17	.20	.13	.15	.17
.225	.14	.17	.13	.21	.20	.19	.15	.18
.275	.16	.15	.17	.21	.22	.15	.23	.17
.325	.19	.24	.28	.15	.14	.18	.20	.16
.375	.24	.24	.17	.19	.17	.19	.17	.22
.425	.18	.18	.18	.18	.17	.15	.14	.20
.475	.16	.17	.18	.15	.14	.12	.20	.15
.525	.22	.17	.15	.19	.15	.20	.17	.23
.575	.28	.17	.14	.19	.20	.17	.20	.20
.625	.16	.24	.17	.17	.17	.19	.19	.19
.675	.30	.16	.17	.19	.20	.17	.16	.19
.725	.22	.13	.19	.22	.20	.17	.16	.19
.775	.28	.18	.21	.17	.14	.21	.14	.11
.825	.17	.20	.21	.15	.14	.20	.19	.21
.875	.20	.20	.15	.16	.17	.18	.18	.18
.925	.18	.19	.14	.17	.20	.21	.19	.16
.975	.09	.21	.17	.28	.22	.21	.21	.18

TABLE 7

Comparison of ribbed slab and equivalent plane slab attenuation factors for scattered radiation.

θ_o	Attenuation Factors: Ribbed Slab	Attenuation Factors: Plane Slab	Ratio
0°	0.184±0.001	0.198±0.005	0.93 ± 0.02
45°	0.121±0.003	0.109±0.003	1.11 ± 0.04
60°	0.0640±0.0007	0.0559±0.0020	1.14 ± 0.04
75°	0.0176±0.0007	0.0123±0.0006	1.43 ± 0.09

TABLE 8

Equivalent plane slab attenuation factors for uncollided radiation.

θ_o	Attenuation Factor
0°	0.124
45°	0.0528
60°	0.0158
75°	0.000350

TABLE 9

ATTENUATION FACTORS FOR RADIATION EMITTED INTO DIRECTIONS WITHIN 2.5 DEGREES OF θ_0= 45 DEGREES. THE FRACTIONAL STANDARD DEVIATION HAS AN AVERAGE VALUE OF ABOUT 8 PERCENT FOR THE ATTENUATION FACTORS DUE TO SCATTERED RADIATION ONLY. DATA IN THE TABLES SHOULD BE MULTIPLIED BY 0.1 TO GET THE CORRECT ATTENUATION FACTORS.

X \ H	.49	.98	1.47	1.96	2.94	3.92	4.90	5.88
	SCATTERED RADIATION							
.025	.88	1.18	1.42	1.17	1.22	1.26	1.13	1.20
.075	.83	1.22	1.32	1.22	1.26	1.27	1.20	1.19
.125	.63	1.21	1.13	1.26	1.10	1.19	1.14	1.30
.175	.82	1.28	1.12	1.14	1.07	1.19	1.18	1.17
.225	.85	1.17	1.12	1.17	1.10	1.30	1.32	1.18
.275	.97	1.32	1.19	1.16	1.22	1.28	1.31	1.36
.325	1.29	1.11	1.10	1.50	1.14	1.09	1.12	1.12
.375	1.22	1.14	1.25	1.24	1.11	1.26	1.05	1.17
.425	1.40	1.29	1.11	1.28	1.27	1.33	1.14	1.01
.475	1.39	1.12	1.14	1.15	1.24	1.26	1.16	1.29
.525	1.34	1.18	1.27	1.15	1.06	1.25	1.27	1.14
.575	1.45	1.19	1.20	1.08	1.29	1.25	1.40	1.28
.625	1.53	1.13	1.21	1.35	1.07	1.15	1.17	1.26
.675	1.38	1.28	1.20	1.17	1.29	1.26	1.33	1.10
.725	1.49	1.42	1.14	1.27	1.14	1.04	1.19	1.28
.775	1.65	1.07	1.24	1.15	1.33	1.19	1.11	1.17
.825	1.51	1.23	1.17	1.16	1.25	1.23	1.24	1.19
.875	1.21	1.28	1.26	1.04	1.35	1.20	1.36	1.30
.925	1.34	1.12	1.28	1.33	1.32	1.18	1.21	1.20
.975	1.00	1.24	1.31	1.18	1.36	1.00	1.15	1.26
	SCATTERED PLUS UNSCATTERED RADIATION							
.025	1.33	1.90	1.85	1.97	2.05	2.07	1.87	1.96
.075	1.16	2.17	1.64	2.18	2.26	2.18	2.05	1.99
.125	.88	2.37	1.38	2.43	2.15	2.09	1.96	2.10
.175	1.01	2.57	1.33	2.36	2.07	2.07	1.99	1.97
.225	1.05	2.55	1.33	2.36	2.09	2.18	2.13	1.97
.275	1.17	2.71	1.42	2.36	2.22	2.13	2.03	2.00
.325	1.50	2.42	1.37	2.61	2.04	1.81	1.73	1.67
.375	1.48	2.20	1.60	2.15	1.93	1.91	1.60	1.69
.425	1.76	2.08	1.56	2.05	1.96	1.97	1.68	1.53
.475	1.87	1.70	1.75	1.74	1.86	1.87	1.74	1.86
.525	2.00	1.61	2.06	1.59	1.58	1.83	1.91	1.82
.575	2.33	1.51	2.16	1.42	1.71	1.81	2.05	2.07
.625	2.70	1.38	2.37	1.62	1.42	1.66	1.90	2.06
.675	2.73	1.49	2.45	1.42	1.63	1.76	2.06	1.89
.725	2.88	1.62	2.46	1.51	1.49	1.57	1.85	2.05
.775	3.04	1.27	2.55	1.41	1.71	1.76	1.74	1.90
.825	2.91	1.46	2.38	1.48	1.71	1.81	1.87	1.81
.875	2.31	1.58	2.24	1.45	1.93	1.81	2.02	1.87
.925	2.15	1.51	2.06	1.88	1.96	1.85	1.85	1.78
.975	1.61	1.77	1.89	1.87	2.08	1.77	1.80	1.90

done for the equivalent plane slab using the same computer code that was used for the ribbed slab calculation. 10,000 histories were processed for each angle of incidence. The attenuation factor for the equivalent plane slab and the average attenuation factor for the ribbed slab are compared in Table 7. The results indicate that for normal incidence the attenuation factor for scattered radiation is about 7% less for the ribbed slab than for the equivalent plane slab. On the other hand, for $\theta_o = 75^o$, the ribbed-slab attenuation factor is about 40% greater than the plane-slab attenuation factor. For the sake of completeness, the equivalent plane slab attenuation factors for the uncollided radiation are presented in Table 8.

C. Results for an Imperfectly Collimated Plane Source

The gamma ray source used in the experimental ribbed-slab studies did not produce a perfectly collimated beam of radiation. In order to approximate the effect of the diverging beam on the attenuation factor, consider a plane source which emits radiation isotropically for $42.5^o \leq \theta_o \leq 47.5^o$ and $-\frac{\delta}{2} \leq \omega_o \leq \frac{\delta}{2}$. If the ribbed slab is not present, then the exposure measured by a detector near the plane source will be proportional to

$$\frac{\pi}{180^o}\int_{42.5^o}^{47.5^o} d\theta_o \frac{\sin\theta_o}{\cos\theta_o} \int_{-\frac{\delta}{2}}^{\frac{\delta}{2}} d\omega_o = \delta \ln \frac{\cos 42.5^o}{\cos 47.5^o} .$$

With the same proportionality constant, the exposure when the ribbed slab is present will be proportional to

$$\frac{\pi}{180^o}\int_{42.5^o}^{47.5^o} d\theta_o \sin\theta_o \int_{-\frac{\delta}{2}}^{\frac{\delta}{2}} d\omega_o \frac{A_f(\theta_o,H,X)}{\cos\theta} \approx \frac{\delta\,\pi}{180^o}\int_{42.5^o}^{47.5^o} d\theta_o \sin\theta_o \frac{A_f(\theta_o,H,X)}{\cos\theta_o} .$$

The attenuation factor for the diverging beam can then be defined as

$$A_f(\Delta\theta_o,H,X) = \frac{\pi}{180^o}\int_{42.5^o}^{47.5^o} d\theta_o \sin\theta_o \frac{A_f(\theta_o,H,X)}{\cos\theta_o} \Bigg/ \ln \frac{\cos 42.5^o}{\cos 47.5^o} .$$

To evaluate the integral, additional attenuation factors were computed for radiation incident on the ribbed slab with $\theta_o = 42.5^o$ and $\theta_o = 47.5^o$.

For each of these angles 10,000 histories were analyzed. Then, using attenuation factors for $\theta_o = 42.5^o$, 45^o, and 47.5^o, the integral was evaluated numerically using the trapizoidal rule. Discontinuities in the derivative of the integrand were ignored in the calculation.

Data for $A_f(\Delta\theta_o,H,X)$ are given in Table 9 and are presented graphically in Figure 7. Irregularities due to uncollided radiation diminish with increasing H, in contrast to the situation for a perfectly collimated beam. The rate with which $A_f(\Delta\theta_o,H,X)$ loses its dependence on X as H increases is expected to be greater, the larger the angle of divergence of the beam of incident radiation.

IV. CONCLUSION

When the height of the detector above the slab is about equal to the rib height, the data in this report show that the attenuation factor for scattered radiation depends strongly on the horizontal detector position. However, when the detector height above the end of the ribs becomes equal to or greater than an appreciable fraction of the rib separation distance, the attenuation factor appears to be independent of the horizontal position. It is of interest to note that if the attenuation factor is averaged over one rib-separation distance, the average value is not equivalent to the corresponding attenuation factor for a plane slab having the same average mass thickness as the ribbed slab. For radiation normally incident on the slab the average attenuation factor for the ribbed slab is about 7% smaller than that for the equivalent plane slab. On the other hand, for radiation incident at grazing angles, the data indicate that the average attenuation factor for the ribbed slab is about 40% greater than the value for the equivalent plane slab.

When uncollided radiation is included in the attenuation factor, then it is found that for a perfectly collimated plane parallel beam of radiation incident on the slab, the attenuation factor retains a dependence on the horizontal detector position for all detector-slab separation distances. When the beam of radiation incident on the slab contains radiation traveling in a small cone of directions, then the total attenuation factor slowly loses its dependence on the horizontal detector position as the detector-slab separation distance increases.

Since the data in this report are for a particular ribbed slab configuration, it is not possible to make broad generalizations about the effects of inhomogeneities in shields. However, the present results indicate that in some cases there are sufficiently large differences between the shielding capabilities of inhomogeneous slabs and homogeneous slabs with equivalent average mass thicknesses to make further study desirable.

REFERENCES

1. Clark, Francis H., "Variance of Certain Flux Estimates Used in Monte Carlo Calculations," Nuclear Science and Engineering, Vol. 27, pp. 235-239 (1967).

2. Hubbell, J. H. and Berger, M. J., "Photon Attenuation and Energy Absorption Coefficients, Tabulations and Discussion," to be published in Engineering Compendium on Radiation Shielding, Springer-Verlag, Berlin and New York.

3. Morris, E. E. and Chilton, A. B., "Monte Carlo Calculation of the Spectrum of Gamma Radiation from a Collimated Co-60 Source," University of Illinois, NRSS No. 6, December 1967.

4. Chilton, A. B., Personal Communication.

5. Kahn, H., "Applications of Monte Carlo," USAEC Report R-1237, April 1954.

6. Kimel, William R., (ed.), Radiation Shielding, Analysis and Design Principles as Applied to Nuclear Defense Planning, Office of Civil Defense and Kansas State University, TR 40, November 1966.

TABLE OF FIGURES

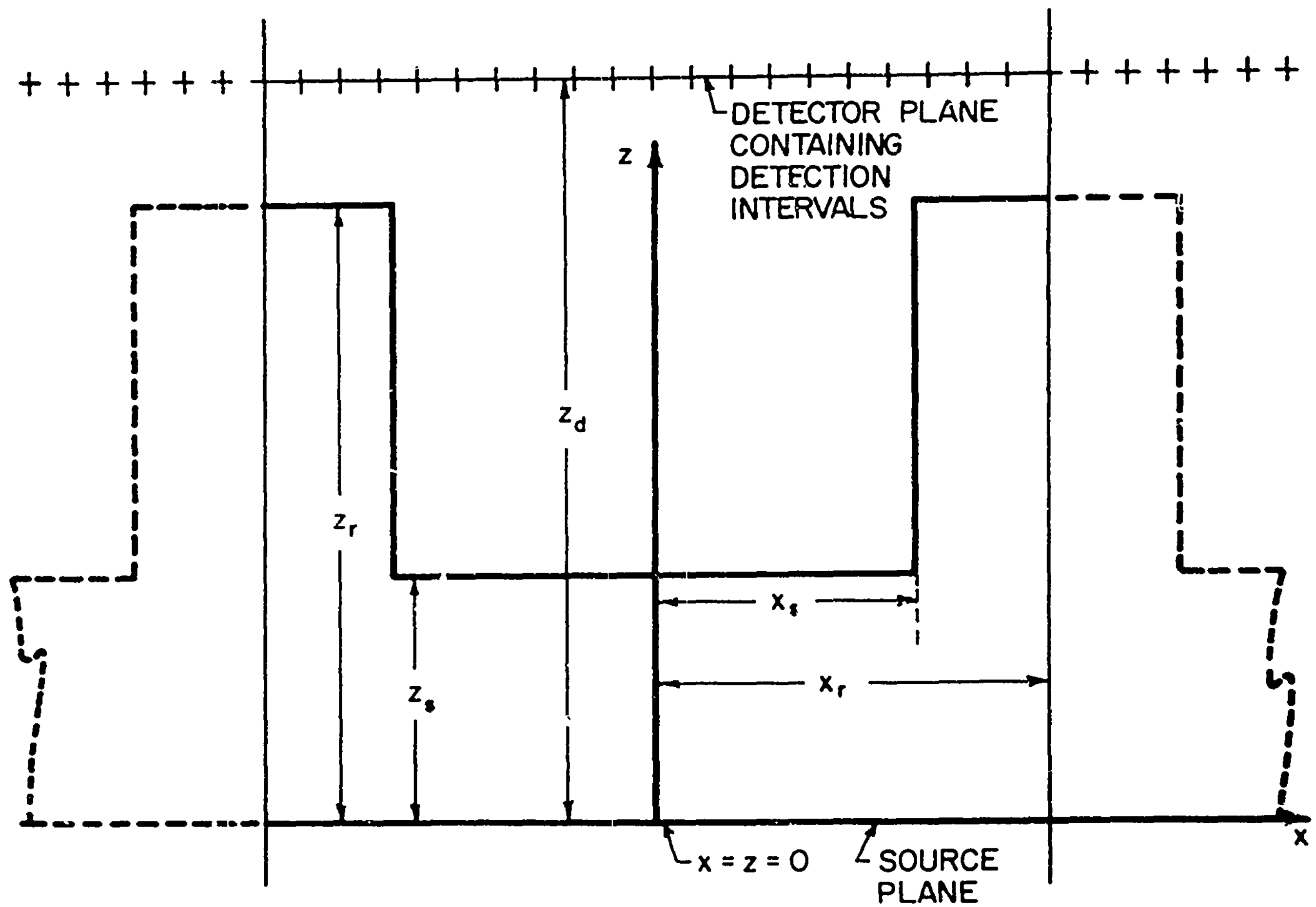

FIGURE 1

A cross-sectional view of the ribbed-slab, defining the various parameters used to describe the geometry.

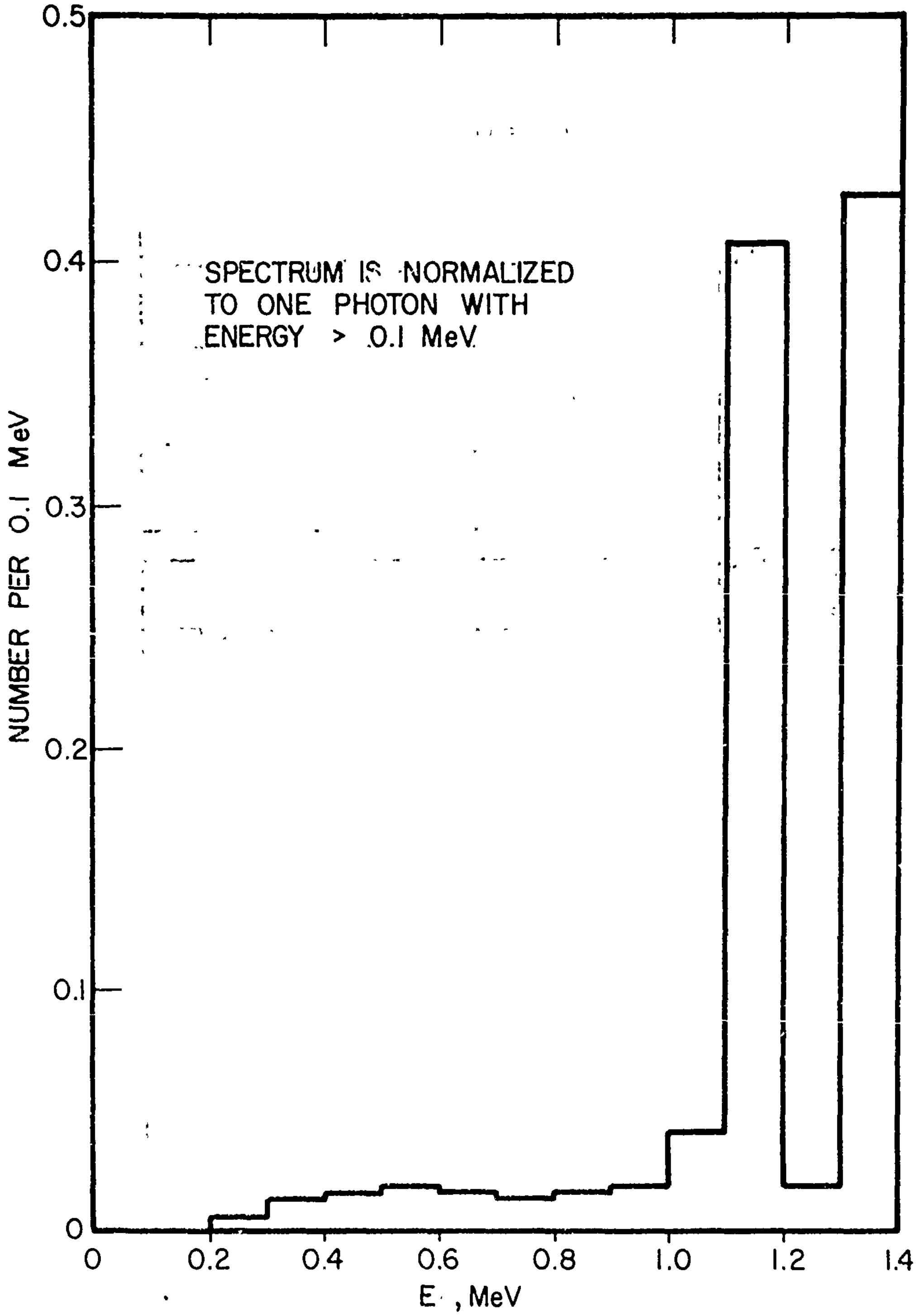

FIGURE 2

Energy spectrum of radiation assumed incident on the ribbed slab.

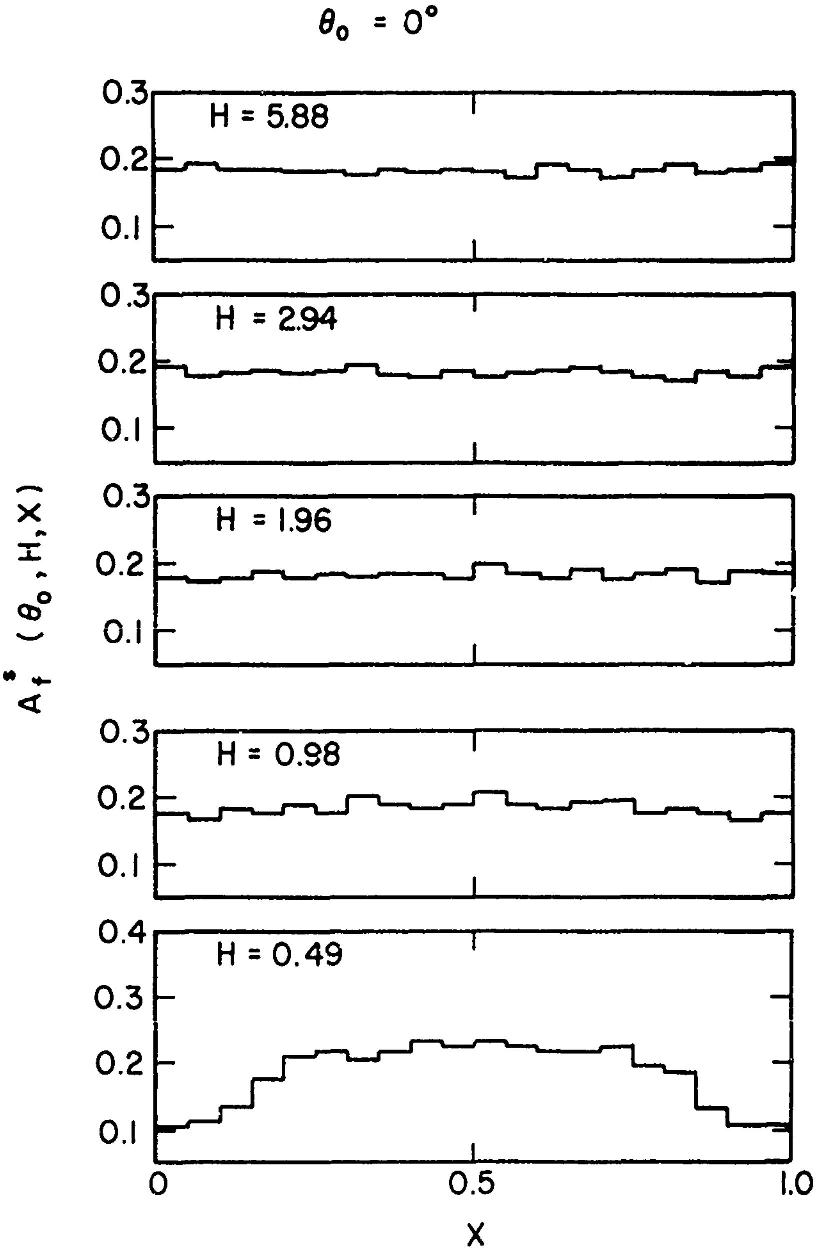

FIGURE 3

Attenuation factors for scattered radiation when $\theta_o = 0^o$.

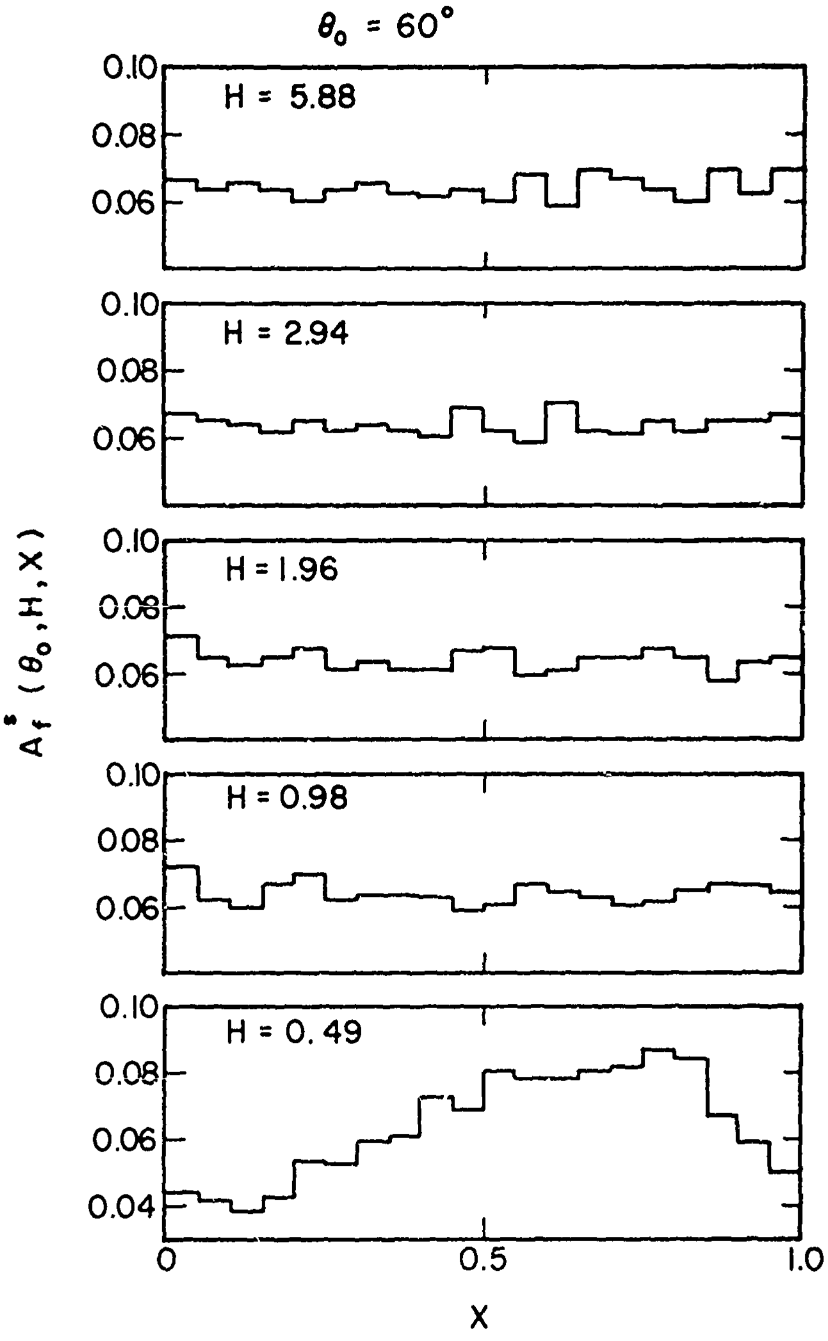

FIGURE 4

Attenuation factors for scattered radiation when $\theta_o = 60^o$.

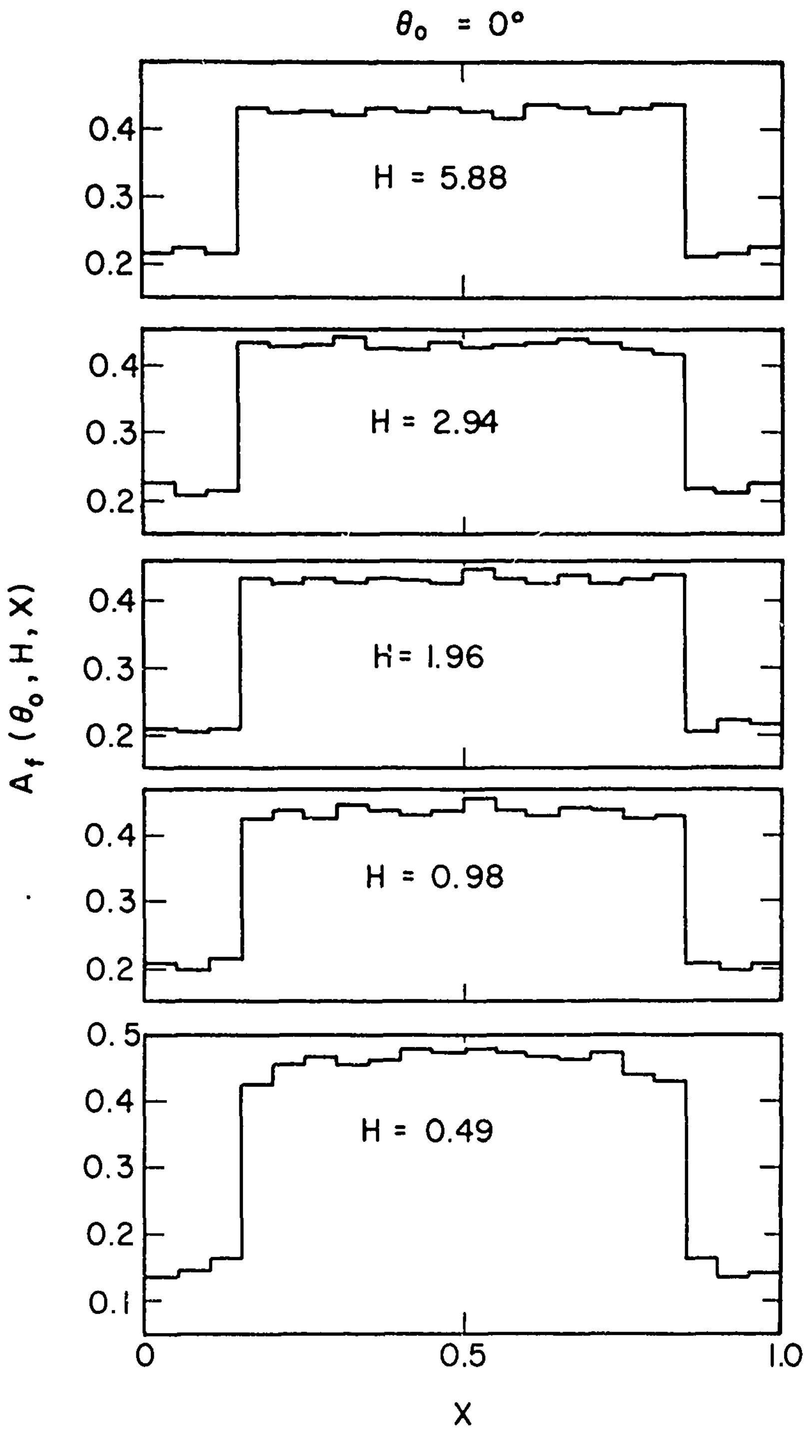

FIGURE 5

Attenuation factors for $\theta_0 = 0^o$ with uncollided radiation included.

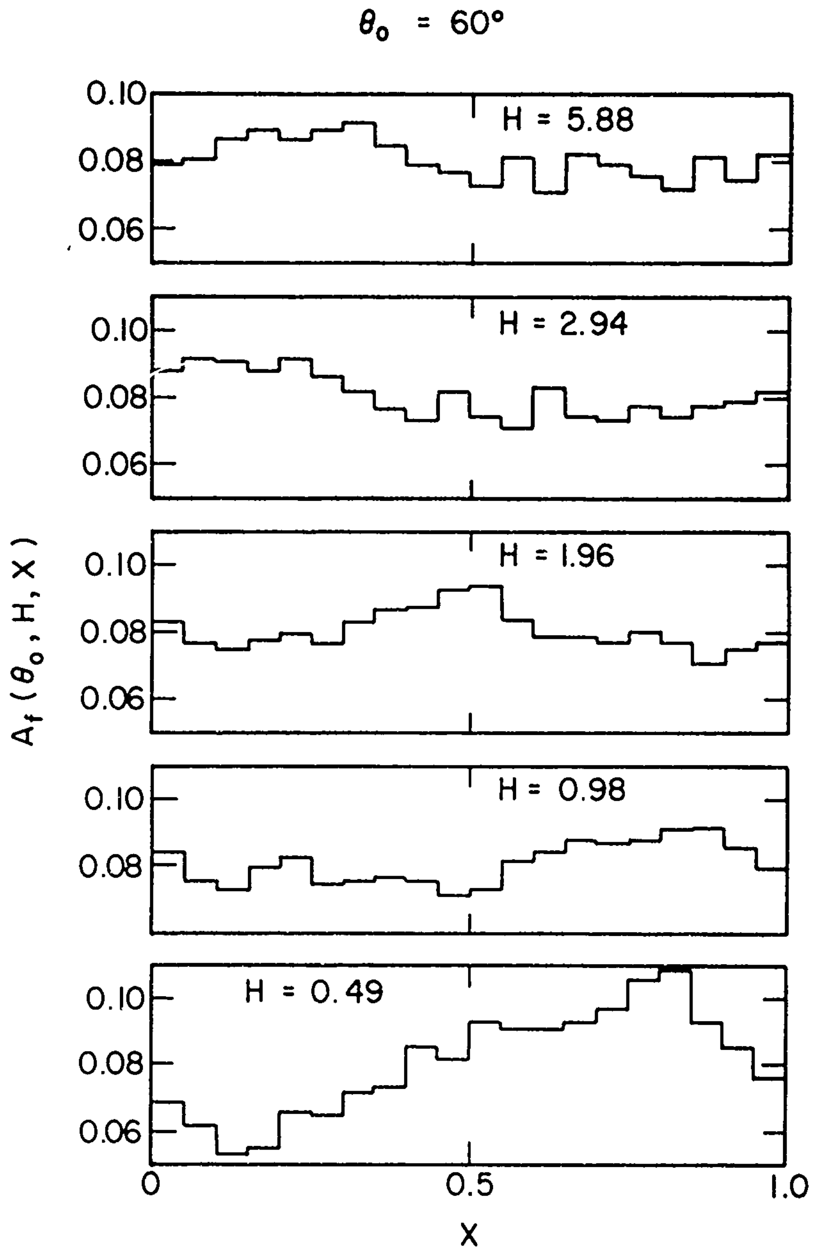

FIGURE 6

Attenuation factors for $\theta_o = 60^o$ with uncollided radiation included.

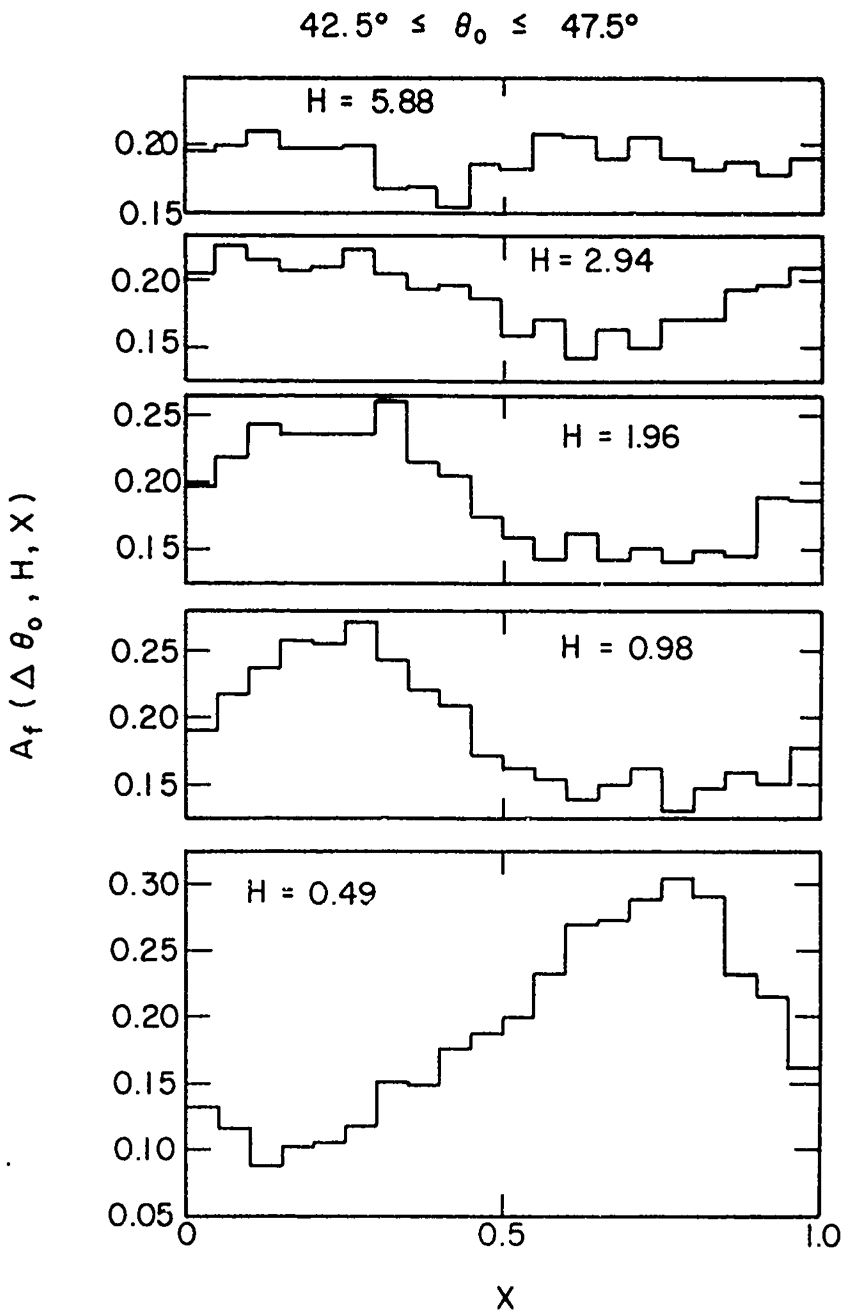

FIGURE 7

Attenuation factors for a beam of radiation incident on the ribbed slab with directions of incidence diverging 2.5° on either side of $\theta_o = 45^o$. Uncollided radiation is included.

APPENDIX A

Calculation for a Simulated Wood Floor

The wood was assumed to have photon interaction properties of concrete having a density of 0.641 g/cm^3. The linear dimensions were chosen to correspond closely to a 1-1/2 inch floor supported by 2- by 10-inch joists spaced 16 inches apart (measured center to center). These dimensions require that

x_r = 8 inches;

x_s = 7 inches;

z_s = 1-1/2 inches;

z_r = 11-1/2 inches.

The source radiation was assumed to have the energy 1.25 MeV and to be incident normally on the floor.

The data for this calculation are presented in Table A1. For this case, 100,000 photon histories were analyzed. The calculation required less than four minutes on the IBM-7094. Like the attenuation factors for scattered radiation presented in Section III, the attenuation factors for the simulated wood floor exhibit a strong dependence on horizontal detector position when the detector height is about equal to the rib height. When the detector height above the ribs exceeds an appreciable fraction of the rib separation distance, the dependence on the horizontal detector position is no longer evident. Unlike the attenuation factors for scattered radiation given in Section III, for detector heights about equal to the rib height, the attenuation factors for the simulated wood floor have their maximum value for detector positions over the ribs. This results because the floor thickness is on the order of 0.1 mfp while the rib heights is on the order of 1 mfp. Thus, radiation incident under the ribs is more likely to be scattered before leaving the ribbed slab.

TABLE A1

ATTENUATION FACTORS FOR 1.25 MEV GAMMA RADIATION INCIDENT NORMALLY ON A SIMULATED WOOD FLOOR. THE FRACTIONAL STANDARD DEVIATION HAS AN AVERAGE VALUE OF ABOUT 5 P5RCENT FOR THE ATTENUATION FACTORS DUE TO SCATTERED RADIATION ONLY. DATA IN THE TABLES SHOULD BE MULTIPLIED BY 0.1 TO GET THE CORRECT ATTENUATION FACTOR.

X \ H	.62	.78	.91	1.16	1.41	1.91	2.16	2.91
				SCATTERED RADIATION				
.025	1.55	1.44	1.38	1.17	1.25	1.31	1.30	1.23
.075	1.31	1.36	1.31	1.35	1.15	1.17	1.32	1.29
.125	1.31	1.28	1.18	1.31	1.26	1.21	1.29	1.32
.175	1.15	1.28	1.28	1.17	1.28	1.25	1.23	1.28
.225	1.16	1.22	1.20	1.27	1.19	1.36	1.26	1.26
.275	1.21	1.21	1.36	1.19	1.24	1.24	1.29	1.20
.325	1.20	1.07	1.23	1.24	1.26	1.26	1.30	1.34
.375	1.00	1.18	1.22	1.25	1.31	1.17	1.28	1.22
.425	1.16	1.21	1.20	1.31	1.29	1.25	1.19	1.26
.475	1.18	1.19	1.21	1.28	1.28	1.25	1.17	1.19
.525	1.19	1.14	1.22	1.30	1.28	1.33	1.19	1.33
.575	1.09	1.21	1.23	1.30	1.25	1.19	1.28	1.25
.625	1.16	1.15	1.23	1.23	1.20	1.21	1.31	1.31
.675	1.16	1.15	1.17	1.19	1.28	1.27	1.20	1.29
.725	1.13	1.32	1.24	1.29	1.18	1.26	1.19	1.19
.775	1.19	1.33	1.27	1.22	1.31	1.26	1.25	1.29
.825	1.31	1.26	1.30	1.25	1.27	1.28	1.30	1.16
.875	1.43	1.37	1.27	1.27	1.29	1.37	1.32	1.21
.925	1.51	1.38	1.34	1.25	1.28	1.29	1.25	1.27
.975	1.72	1.39	1.29	1.31	1.30	1.21	1.23	1.24
				SCATTERED PLUS UNSCATTERED RADIATION				
.025	5.00	4.89	4.83	4.62	4.70	4.76	4.75	4.68
.075	10.02	10.07	10.02	10.06	9.85	9.87	10.03	9.99
.125	10.01	9.98	9.88	10.01	9.97	9.91	10.00	10.03
.175	9.86	9.99	9.99	9.87	9.99	9.95	9.93	9.98
.225	9.87	9.92	9.90	9.97	9.90	10.06	9.96	9.96
.275	9.92	9.91	10.07	9.89	9.94	9.94	9.99	9.91
.325	9.90	9.77	9.93	9.94	9.96	9.96	10.01	10.04
.375	9.71	9.89	9.92	9.95	10.02	9.87	9.98	9.92
.425	9.87	9.92	9.90	10.01	9.99	9.95	9.90	9.97
.475	9.89	9.90	9.91	9.98	9.98	9.96	9.87	9.89
.525	9.89	9.84	9.92	10.01	9.98	10.03	9.89	10.04
.575	9.79	9.91	9.93	10.01	9.95	9.90	9.98	9.96
.625	9.86	9.85	9.94	9.94	9.90	9.92	10.02	10.02
.675	9.86	9.85	9.88	9.89	9.98	9.97	9.91	10.00
.725	9.83	10.03	9.94	9.99	9.88	9.96	9.89	9.90
.775	9.90	10.03	9.97	9.92	10.01	9.97	9.95	9.99
.825	10.01	9.97	10.00	9.95	9.97	9.98	10.00	9.87
.875	10.14	10.07	9.98	9.97	9.99	10.07	10.03	9.92
.925	10.22	10.08	10.05	9.96	9.98	10.00	9.95	9.97
.975	5.17	4.84	4.74	4.76	4.75	4.66	4.68	4.69

APPENDIX B

1. Description of the Computer Program.

A general description of the calculation of the data in this report has been given in Section II. A somewhat more detailed description of the individual subroutines which make up the computer program will now be undertaken.

ADAM RIB II (Main Program)

Subroutines called: LEARN3, DATEX3, TRACK3, TEACH3.

The main program consists of three loops. The inner loop which the program executes IHPP times for each value of the pair L and NXSØ determines the number of histories to be done for each source point. NXSØ determines the location of a source point and NXSX is the maximum number of source points. L is an index which assumes all values from 1 to LØØP. LØØP is defined below. The product LØØP* NXSX* IHPP determines the total number of histories to be processed.

Subroutine LEARN3

Subroutines called: none.

This subroutine reads all input data and prints them under appropriate labels. The first card read contains 72 alphanumeric characters which when printed identify the run. The input variables will be defined in the order in which they appear in the subroutine.

IHIX: The number of histories to be processed for a given value of the index L in the main program.

NPAX: The number of detector heights to be considered in the calculation.

NDAX: The number of detectors to be considered at a given height.

NMAX: The maximum number of interactions allowed in a given history. For the calculations in this report, this parameter was assigned the value 50.

NMIN: The minimum number of interactions which a photon had to have before it was allowed to contribute to the detector response. For the calculations in this report, this parameter was assigned the value 1. This meant that the Monte Carlo calculation

gave the detector response due to scattered radiation only.

MXAX: The number of energies for which interaction coefficients are read.

NXSX: The number of source points to be located between the centers of two ribs. The distance between rib centers was divided into NXSX intervals and a source point was selected from the center of each interval.

NESX: The number of source energies which makes up the source spectrum.

LØØP: The number of times the main program executes its outer loop. LØØP* IHIX is the total number of histories to be processed in the run.

NRAN: The initial random number read in an octal format, Rules for selecting this number are given in the program listing for the random number subroutine (RAND, A,B,C,D).

XS: Half the distance between adjacent edges of two adjacent ribs.

XR: Half the distance between the centers of two adjacent ribs.

ZS: The thickness of the slab.

ZR: The thickness of the slab plus the height of a rib.

ZP: A list of detector heights measured from the side of the slab opposite the ribs.

UZCT: The cosine cutoff described in Section II. B.

CTHØ: The initial value of the direction cosine u_z.

PHØ: This angle, read in degrees, defines the initial direction cosine relative to the x-axis. We have

$$u_x = \sqrt{1 - \text{CHTØ}^2} \cos(\text{PHØ}).$$

DEN: The density of the ribs and the slab. In the calculation described in this report, the units for this quantity were grams per square centimeter per inch.

EB: A list of energies in MeV for which interaction coefficients are to be read.

DUM1
DUM2
DUM3
These variables are used to skip interaction coefficient data on the input cards which are not used in the calculation.

XSECB: The array containing the input interaction coefficient data. The pair of indices (M,1) refers to the Compton interaction coefficient, (M,2) to the pair production interaction coefficient, (M,3) to the total attenuation coefficient, and (M,4) to the energy absorption coefficient for air. For the calculations described in this report, all these quantities had units square centimeter per gram.

EMIN: The cutoff energy.

ESØ: A list of energies representing the source spectrum.

WTSØ: A list of probabilities assigned to the list of source energies ESØ.

Subroutine DATEX3

Subroutines called: TABIN

This subroutine performs a number of preliminary tasks in preparation for the main part of the calculation. First, the interaction coefficient data are modified so that they will contain data more directly useful in later stages of the calculation. XSECB(M,1) is changed to the probability that given an interaction, either a Compton scattering or a pair production interaction will occur. XSECB (M,2) is multiplied by the density DEN to convert it to units consistent with the units used in specifying the dimensions of the slab and ribs.

Second, the logarithm of each entry in the array XSECB and the list EB is calculated. Double logarithmic interpolation is then used to expand the tables of interaction probabilities. Entries in these expanded tables correspond to energies defined by the formula

$$E = \frac{1000}{NE + 90.5} - 1 \; ; \quad 1 \le NE \le 899 \quad .$$

In subsequent parts of the program, if an interaction probability is desired for a certain photon energy E , the index NE is defined by rounding the following point number

$$\frac{1000}{E + 1} - 90$$

down to the nearest whole number. Then the interaction probability corresponding to the index NE is taken as the interaction probability

for photons of energy E . This particular table-look-up algorithm was suggested by A. B. Chilton[4].

Third, a table of sines and cosines is generated for 360 angles starting at 0.5° and proceeding in steps of 1° up to and including 359.5° . The sine and cosine of a randon angle between 0° and 360° are then selected by computing an index according to the formula NPH = 360.0*RAN, where RAN is a random number uniformly distributed on the interval (0,1) and then choosing the sine and cosine in this table corresponding to the index NPH + 1 .

Fourth, the quantities XR2 and XS2 are computed. These give the distance between rib centers and the separation distance between adjacent edges of the ribs, respectively.

Fifth, the cutoff energy EMIN is converted to its corresponding Compton wavelength WMAX .

Sixth, a list of source-point coordinates XSØ is computed. These are defined by dividing the interval between the centers of two adjacent ribs into NXSX increments and selecting the midpoint of each increment as a source point.

Seventh, a check is made to see if the input parameter IHIX is divisible by the number of source points NXSX . If this is not the case, then the program terminates.

Eighth, IRC is set equal to the initial random number IRAN , the sine of the angle of incidence is computed, and the sine and cosine of the angle PHØ are calculated.

Ninth, the arrays and lists which are used to accumulate individual scores and the squares of individual scores are initially set equal to zero. The names of these variables are defined as follows:

TS2N: This variable is used to accumulate the statistical weight of a photon when it is transmitted. After division by the total rumber of histories, it gives the number current of photons transmitted by the ribbed slab.

TF2N: This variable is used to accumulate individual contributions to the transmitted number flux.

TFEX: This variable is used to accumulate individual contributions to the exposure due to transmitted photons.

BSCN: This list is used to accumulate contributions to the reflected number current as a function of the position of emergence relative to the ribs.

BSFN: This list is used to accumulate contributions to the reflected number flux as a function of the position of emergence.

EBSC: This list is used to accumulate contributions to the exposure made by reflected photons, again as a function of the point of emergence.

TS1N: This array is used to accumulate contributions to the transmitted number current as a function of the height of the detector above the slab and the horizontal position of the detector relative to the ribs.

TSFN: This array is used to accumulate contributions to the exposure due to transmitted photons as a function of detector height and horizontal detector position.

The cosine cutoff described in Section II is applied only to the arrays TSFN and TESC . For each of the variables listed above there is a second variable named by attaching the symbol 2 to the end of the names listed. These variables are used to accumulate the squares of individual contributions so that standard deviations can be calculated at the end of the run.

Tenth, the probabilities for individual source energies are used to calculate a cumulative probability distribution for the source energies. This cumulative distribution is then used in the random sampling of the initial photon energy. The program normalizes the probability distribution and the resulting cumulative distribution.

Subroutine TRACK3

Subroutines called: RANDC, RANDA, CHECK3, CØMPT3, GRADE3.

This subroutine generates path lengths between interaction points and decides what kind of interactions take place. The first part of the program establishes the initial photon energy, direction, and position. The random numbers used within a given history are generated by subroutine RANDA . However, this chain of random numbers is initialized at the beginning of each history using a random number generated by subroutine RANDC. The total number of random numbers generated by RANDC will be equal to the number of histories. The y-

coordinate is defined and carried along in this subroutine, but this is unnecessary and could be eliminated. WT is the statistical weight of the photon and is initially set equal to unity. The integer N is used to count the number of interactions in a given history. When a photon escapes from the slab, N is compared with NMIN to see if a score should be recorded. If N exceeds NMAX , the history is terminated.

Once the initial conditions have been defined, the track length to the next interaction is sampled and the coordinates of the location of this interaction are computed. Then subroutine CHECK3 is called to determine if any boundaries have been crossed. If a boundary has been crossed CHECK3 makes appropriate adjustments on the location of the interaction and defines NSCT . If NSCT is negative; then the photon has escaped and TRACK3 decides whether or not a score should be recorded. If NSCT = 0, then CHECK3 found that the position of the interaction point was not in the ribbed slab but that when the photon was moved along the direction it was going, it subsequently re-entered the slab. In this case, TRACK3 samples a new track length to move the photon away from the boundary of the ribbed slab and into the slab or rib.

If NSCT > 0, then an interaction point within the slab has resulted. If the index NE is equal to 404, the photon energy is very nearly equal to the threshold energy for pair production. Thus, if NE < 404, TRACK3 must choose between a pair-production interaction and a Compton scattering. If NE > 404, only Compton scattering is allowed. When a pair-production interaction is selected, the photon energy is set equal to 0.511 MeV (Compton wavelength is unity and NE = 571), its statistical weight is multiplied by two, and a new direction is sampled from an isotropic angular distribution. Sampling a new direction and energy in the case of Compton scattering is accomplished by subroutine CØMPT3.

Photoelectric absorption is taken into account by multiplying the statistical weight of the photon by SURV, the probability that an interaction is a pair production or a Compton scattering given that an interaction occurs.

Subroutine CHECK3

Subroutines called: none.

This subroutine checks to see if boundaries have been crossed. Most of the questions asked by the subroutine are phrased for photons whose direction cosine along the x-direction is positive. If this direction cosine is negative, then the transformation

$$UX \rightarrow -UX = PUX$$
$$XN \rightarrow -XN$$

is made and the photon is treated as if the direction cosine were positive. This transformation is permissible because the origin of the x-coordinate is located halfway between the ribs.

Basically, the subroutine checks for four events. First it checks to see if the photon has been transmitted by the ribbed slab. If it has, the x-coordinate of the point where the photon crossed the plane defined by the top of the ribs is computed and NSCT is set = -1.

Second, the subroutine checks to see if the photon has been reflected by the slab. If reflection has occured, the x-coordinate of the reflection point is computed and NSCT is set = -1.

Third, the subroutine checks to see if the photon has left the ribbed slab. If this is the case, then either the photon has actually been transmitted or the photon will re-enter the ribbed slab. If transmission has occured, then the x-coordinate of the point where the photon crosses the plane defined by the top of the ribs is computed and NSCT is set = -1. Otherwise the coordinates of the point where the photon re-enters the slab are determined and NSCT is set = 0.

Fourth, the subroutine checks to see if the x-coordinate of the photon has exceeded the x-coordinate of the rib center. If this has happened, then the separation distance between the rib centers is subtracted from the x-coordinate of the photon and the question is asked again. This process is continued until an x-coordinate is obtained which is less than the x-coordinate of the rib center.

Once the subroutine determines that the photon has not been reflected or transmitted by the slab, and that the photon has not left and re-entered the slab, then it sets NSCT = 1 .

Subroutine CØMPT3

Subroutines called: RANDA.

This subroutine uses the method of Kahn[5] to sample a new photon direction and energy from the Klein-Nishina distribution.

Subroutine GRADE3

Subroutines called: none.

This subroutine computes scores in the event that a photon is reflected or transmitted by the ribbed slab. The variables in which the scores are accumulated are defined in the description for subroutine DATEX3.

If a photon is reflected, its contribution to the reflected number current, number flux, and exposure is computed as a function of the position of emergence of the photon. Because the albedo was of only minor interest in the present study, the additional complication of the cosine cutoff discussed in Section II was not introduced in the computation of reflected number flux and exposure.

When a photon is transmitted, its contribution to the transmitted number current, number flux, and exposure is computed in two ways. First, the contribution is recorded without taking into account the x-coordinate of the photon when it left the ribbed slab. In this case, the cosine cutoff described in Section II was not used in the calculation of number flux and exposure. Second, the contribution is recorded as a function of detector height above the slab and horizontal detector position. In this second case, the cosine cutoff described in Section II was used in the calculation of number flux and exposure. By averaging the number flux and exposure (calculated using the second method) over all horizontal detector positions and comparing with the results obtained using the first method it was possible to estimate the error introduced by the cosine cutoff.

Subroutine TEACH3

Subroutines called: RIBTAB, DIRIB.

This subroutine normalizes and prints the output data. It also computes fractional standard deviations for all results. Headings are printed with all the data so that the output is fairly self-explanatory.

In addition, this subroutine calls subroutine DIRIB which computes the contribution to the exposure due to uncollided radiation. These results are then added to the data obtained in the Monte Carlo calculation. Because of an oversight there is no provision in the program for determining whether the direct contribution should be added in. If for example the direct radiation is included in the Monte Carlo calculation, then TEACH3 will add this contribution as calculated by DIRIB anyway with the result that some of the output tables will be incorrect.

The subroutine also punches the ribbed slab attenuation factors and the errors of the attenuation factors on cards.

Subroutine DIRIB

Subroutines called: TABIN

This subroutine computes the contribution to the exposure due to uncollided radiation as a function of the horizontal detector position XD and the distance between the detector and the source plane ZP . The result is returned to TEACH3 by means of the argument DIR . The direction of the uncollided radiation is specified by CPHØ and CTHØ . The horizontal detector position is taken as the midpoint of the detection intervals described in Section II.

The bulk of the program is taken up with the calculation of the path length which the uncollided radiation must travel within the ribbed slab in order to reach the detector. This calculation must take account of the fact that in addition to passing through the basic slab, the radiation may pass through parts of one or more ribs. The calculation is straightforward but rather tedious.

After the path length T has been computed, the last part of the program computes the contribution to the exposure made by each energy in the source spectrum.

Subroutine RIBTAB

Subroutines called: none.

This subroutine prints tables of data as a function of detector height and horizontal detector position. Because several of these tables are printed, this part of TEACH3 was separated into a second subroutine to save coding.

The maximum table width is eleven columns. If more than eleven columns are needed, then the additional columns are included in a second table which is printed below the first table.

Subroutine TABIN

Subroutines called: none.

This subroutine performs a quadratic interpolation simultaneously on NMAX functions $f_m(x)$. It is assumed that the functions are known at NMAX values x_n . The program assumes that the values x_n are stored in descending order. The list x_n is denoted by XB(N) and the array $f_m(x_n)$ by FB(N,M) . The point where the interpolated values are to be found is given by X and the interpolated values by F(M) . Unless X is closest to the initial or final entries in the list XB(N) , the central point in the three-point interpolation is taken as the value in the list which is closest to X .

The first time the program is called, the parameter NTABIN should have the value one . Then certain differences, products, and sums which are needed each time the subroutine is called are computed and stored. NTABIN is then set equal to two and on subsequent calls, these quantities are not recomputed.

Subroutine RANDA,B,C,D

Subroutines called: none.

This subroutine is actually four subroutines in one. It is used to calculate pseudorandom numbers, uniformly distributed on the interval (0,1) . The multiplicative congruential method with modulus 2^{35} is used. If the calling statement is

CALL RANDA (IR,R)

the multiplier is 5^{15} . If the terminal letter on the subroutine name is B,C, or D, the multiplier is 5^{13}, 5^{11}, or 5^{9}, respectively. The argument IR is the integral form of the random number and R is the normalized form. IR must be supplied by the user the first time the subroutine is called.

Except for some unimportant comment cards at the beginning, this subroutine is identical to one described in more detail by Spencer[6].

2. Program Listings and Sample Output

Listings of the programs described above are given on the following pages. A sample output from the program follows the listings.

```
$       FASTRAN
C      ADAM RIB II                           6-7-67
       COMMON BSCN,BSCN2,BSFN,BSFN2,CPH,CPHO,CTHO,DEN,EB,EBSC,EBSC2,
     1 EMIN,ESO,EXC,FNDAX,IHIX,IHPP,IRA,IRC,LOOP,MXAX,NDAX,NE,NESO,
     2 NESX,NMAX,NMIN,NPAX,NRAN,NSCT,NXSO,NXSX,PCS,PHO,RAN,S,SPH,
     3 SPHO,STHO,SURV,SUZ,TESC,TESC2,TFEX,TFEX2,TF2N,TF2N2,TSFN,TSFN2,
     4 TS1N,TS1N2,TS2N,TS2N2,UT,UX,UY,UZ,UZCT,W,WMAX,WT,WTSO,WTSOC,
     5 X,XN,XR,XRS,XR2,XS,XS2,XSECB,XSO,Y,YN,Z,ZN,ZP,ZR,ZS
       DIMENSION BSCN(30),BSCN2(30),BSFN(30),BSFN2(30),CPH(360),
     1 EB(25),EBSC(30),EBSC2(30),ESO(30),EXC(899),PCS(404),SPH(360),
     2 SURV(899),TESC(30,30),TESC2(30,30),TSFN(30,30),TSFN2(30,30),
     3 TS1N(30,30),TS1N2(30,30),UT(899),WTSO(30),WTSOC(30),
     4 XSECB(25,4),XSO(80),ZP(30)
       CALL LEARN3
       CALL DATEX3
       DO 30 L=1,LOOP
       NXSO=0
    10 NXSO=NXSO+1
       DO 20 J=1,IHPP
    20 CALL TRACK3
       IF(NXSO-NXSX)10,30,30
    30 CONTINUE
       CALL TEACH3
       CALL SYSTEM
       END
```

```
$       FASTRAN
C      SUBROUTINE LEARN3                           6-12-67
       SUBROUTINE LEARN3
       COMMON BSCN,BSCN2,BSFN,BSFN2,CPH,CPHO,CTHO,DEN,EB,EBSC,EBSC2,
     1 EMIN,ESO,EXC,FNDAX,IHIX,IHPP,IRA,IRC,LOOP,MXAX,NDAX,NE,NESO,
     2 NESX,NMAX,NMIN,NPAX,NRAN,NSCT,NXSO,NXSX,PCS,PHO,RAN,S,SPH,
     3 SPHO,STHO,SURV,SUZ,TESC,TESC2,TFEX,TFEX2,TF2N,TF2N2,TSFN,TSFN2,
     4 TS1N,TS1N2,TS2N,TS2N2,UT,UX,UY,UZ,UZCT,W,WMAX,WT,WTSO,WTSOC,
     5 X,XN,XR,XRS,XR2,XS,XS2,XSECB,XSO,Y,YN,Z,ZN,ZP,ZR,ZS
       DIMENSION BSCN(30),BSCN2(30),BSFN(30),BSFN2(30),CPH(360),
     1 EB(25),EBSC(30),EBSC2(30),ESO(30),EXC(899),PCS(404),SPH(360),
     2 SURV(899),TESC(30,30),TESC2(30,30),TSFN(30,30),TSFN2(30,30),
     3 TS1N(30,30),TS1N2(30,30),UT(899),WTSO(30),WTSOC(30),
     4 XSECB(25,4),XSO(80),ZP(30)
       WOT6,10
 10    FORMAT(1H0)
 15    FORMAT(1H1)
       RIT7,20
       WOT6,20
 20    FORMAT(72H
     1                                                   )
       WOT6,10
       WOT6,30
 30    FORMAT(54H  IHIX   NPAX   NDAX   NMAX   NMIN   MXAX   NXSX   NESX   LOOP)
       RIT7,40,IHIX,NPAX,NDAX,NMAX,NMIN,MXAX,NXSX,NESX,LOOP
       WOT6,40,IHIX,NPAX,NDAX,NMAX,NMIN,MXAX,NXSX,NESX,LOOP
 40    FORMAT(12I6)
       WOT6,10
       WOT6,50
 50    FORMAT(22H INITIAL RANDOM NUMBER)
       RIT7,60,NRAN
       WOT6,60,NRAN
 60    FORMAT(O13)
       WOT6,10
       WOT6,70
 70    FORMAT(31H      XS       XR       ZS       ZR)
       RIT7,80,XS,XR,ZS,ZR
       WOT6,80,XS,XR,ZS,ZR
 80    FORMAT(9F8.3)
       WOT6,10
       WOT6,90
 90    FORMAT(61H DETECTOR PLANE HEIGHTS (MEASURED FROM ENTRANCE FACE OF
     1SLAB))
       RIT7,80,(ZP(NP),NP=1,NPAX)
       WOT6,80,(ZP(NP),NP=1,NPAX)
       WOT6,10
       WOT6,100
 100   FORMAT(35H COSINE CUTOFF FOR FLUX COMPUTATION)
       RIT7,80,UZCT
       WOT6,80,UZCT
       WOT6,10
       WOT6,110
 110   FORMAT(29H COSINE OF ANGLE OF INCIDENCE)
       RIT7,80,CTHO
       WOT6,80,CTHO
       WOT6,10
       WOT6,120
```

```
120 FORMAT(25H AZIMUTH OF INCIDENT BEAM)
    RIT7,80,PHO
    WOT6,80,PHO
    WOT6,10
    WOT6,130
130 FORMAT(25H DENSITY OF SLAB AND RIBS)
    RIT7,80,DEN
    WOT6,60,DEN
    WOT6,15
    WOT6,10
    RIT7,140
    WOT6,140
140 FORMAT(80H
   1                                                                   )
    WOT6,10
    WOT6,150
150 FORMAT(37H ENERGY   COMPTON      PAIR      TOTAL)
    DO 160 M=1,MXAX
    RIT7,170,EB(M),DUM1,XSECB(M,1),DUM2,XSECB(M,2),DUM3,XSECB(M,3)
160 WOT6,170,EB(M),(XSECB(M,I),I=1,3)
170 FORMAT(F7.3,1P7E10.3)
    WOT6,15
    WOT6,10
    WOT6,180
180 FORMAT(39H ENERGY ABSORPTION COEFFICIENTS FOR AIR)
    WOT6,10
    DO 190 M=1,MXAX
    RIT7,170,EB(M),XSECB(M,4)
190 WOT6,170,EB(M),XSECB(M,4)
    WOT6,10
    WOT6,200
200 FORMAT(14H CUTOFF ENERGY)
    RIT7,80,EMIN
    WOT6,80,EMIN
    WOT6,10
    WOT6,210
210 FORMAT(16H SOURCE ENERGIES)
    RIT7,80,(ESO(NESO),NESO=1,NESX)
    WOT6,80,(ESO(NESO),NESO=1,NESX)
    WOT6,10
    WOT6,220
220 FORMAT(22H SOURCE ENERGY WEIGHTS)
    RIT7,230,(WTSO(NESO),NESO=1,NESX)
    WOT6,230,(WTSO(NESO),NESO=1,NESX)
230 FORMAT(1P7E10.2)
    WOT6,10
    RETURN
    END
```

```
$       FASTRAN
C       SUBROUTINE DATEX3                         6-8-67
        SUBROUTINE DATEX3
        COMMON BSCN,BSCN2,BSFN,BSFN2,CPH,CPHO,CTHO,DEN,EB,EBSC,EBSC2,
       1 EMIN,ESO,EXC,FNDAX,IHIX,IHPP,IRA,IRC,LOOP,MXAX,NDAX,NE,NESO,
       2 NESX,NMAX,NMIN,NPAX,NRAN,NSCI,NXSO,NXSX,PCS,PHO,RAN,S,SPH,
       3 SPHO,STHO,SURV,SUZ,TESC,TESC2,TFEX,TFEX2,TF2N,TF2N2,TSFN,TSFN2,
       4 TS1N,TS1N2,TS2N,TS2N2,UT,UX,UY,UZ,UZCT,W,WMAX,WI,WISO,WISOC,
       5 X,XN,XR,XRS,XR2,XS,XS2,XSECB,XSO,Y,YN,Z,ZN,ZP,ZR,ZS
        DIMENSION BSCN(30),BSCN2(30),BSFN(30),BSFN2(30),CPH(360),
       1 EB(25),EBSC(30),EBSC2(30),ESO(30),EXC(899),PCS(404),SPH(360),
       2 SURV(899),TESC(30,30),TESC2(30,30),TSFN(30,30),TSFN2(30,30),
       3 TS1N(30,30),TS1N2(30,30),UT(899),WTSO(30),WTSOC(30),
       4 XSECB(25,4),XSO(80),ZP(30)
        DIMENSION XSEC(4)
        NTABIN=1
        DO 30 M=1,MXAX
        SURVB=(XSECB(M,1)+XSECB(M,2))/XSECB(M,3)
        PCSB=XSECB(M,1)/(XSECB(M,1)+XSECB(M,2))
        XSECB(M,1)=SURVB
        XSECB(M,2)=PCSB
        XSECB(M,3)=XSECB(M,3)*DEN
        DO 20 I=1,4
   20   XSECB(M,I)=ELOG(XSECB(M,I))
   30   EB(M)=ELOG(EB(M))
        MXAX2=MXAX/2
        MM=MXAX+1
        DO 40 M=1,MXAX2
        MM=MM-1
        DUM=EB(M)
        EB(M)=EB(MM)
        EB(MM)=DUM
        DO 40 I=1,4
        DUM=XSECB(M,I)
        XSECB(M,I)=XSECB(MM,I)
   40   XSECB(MM,I)=DUM
        DO 60 NE=1,899
        FNE=NE
        E=1000.0/(FNE+90.5)-1.0
        E=ELOG(E)
        CALL TABIN(NTABIN,XSECB,EB,MXAX,4,E,XSEC)
        SURV(NE)=EXP(XSEC(1))
        UT(NE)=EXP(XSEC(3))
        EXC(NE)=EXP(E+XSEC(4))
        IF(NE-404) 50,50,60
   50   PCS(NE)=EXP(XSEC(2))
   60   CONTINUE
        PH=-0.5
        DO 70 IPH=1,360
        PH=PH+1.0
        PHR=PH *0.017453293
        CPH(IPH)=COS(PHR)
   70   SPH(IPH)=SIN(PHR)
        FNDAX=NDAX
        XR2=2.0*XR
        XS2=2.0*XS
```

```
      WMAX=0.511/EMIN
      FNXSX=NXSX
      DX=XR2/FNXSX
      XX=-XR-DX/2.0
      DO 80 NXSO=1,NXSX
      XX=XX+DX
   80 XSO(NXSO)=XX
      IHPP=IHIX/NXSX
      IF(NXSX*IHPP-IHIX) 90,120,90
   90 WOT 6,100
  100 FORMAT(61H NUMBER OF HISTORIES NOT DIVISIBLE BY NUMBER OF SOURCE P
     1OINTS)
  110 CALL SYSTEM
  120 IRC=NRAN
      STHO=SQRT(1.0-CTHO**2)
      PHO=PHO*0.017453293
      CPHO=COS(PHO)
      SPHO=SIN(PHO)
      TS2N=0.0
      TS2N2=0.0
      TF2N=0.0
      TF2N2=0.0
      TFEX=0.0
      TFEX2=0.0
      DO 130 ND=1,NDAX
      BSCN(ND)=0.0
      BSCN2(ND)=0.0
      BSFN(ND)=0.0
      BSFN2(ND)=0.0
      EBSC(ND)=0.0
      EBSC2(ND)=0.0
      DO 130 NP=1,NPAX
      TS1N(ND,NP)=0.0
      TS1N2(ND,NP)=0.0
      TSFN(ND,NP)=0.0
      TSFN2(ND,NP)=0.0
      TESC(ND,NP)=0.0
  130 TESC2(ND,NP)=0.0
      WTSOC(1)=WTSO(1)
      IF(NESX-1)160,160,140
  140 DO 150 NESO=2,NESX
  150 WTSOC(NESO)=WTSOC(NESO-1)+WTSO(NESO)
  160 DO 170 NESO=1,NESX
      WTSO(NESO)=WTSO(NESO)/WTSOC(NESX)
  170 WTSOC(NESO)=WTSOC(NESO)/WTSOC(NESX)
      RETURN
      END
```

```
$      FASTRAN
C      SUBROUTINE TRAGK3                          6-7-67
       SUBROUTINE TRAGK3
       COMMON BSCN,BSCN2,BSFN,BSFN2,CPH,CPHO,CTHO,DEN,EB,EBSC,EBSC2,
      1  EMIN,ESO,EXC,FNDAX,IHIX,IHPP,IRA,IRC,LOOP,MXAX,NDAX,NE,NESO,
      2  NESX,NMAX,NMIN,NPAX,NRAN,NSCT,NXSO,NXSX,PCS,PHO,RAN,S,SPH,
      3  SPHO,STHO,SURV,SUZ,TESC,TESC2,TFEX,TFEX2,TF2N,TF2N2,TSFN,TSFN2,
      4  TS1N,TS1N2,TS2N,TS2N2,UT,UX,UY,UZ,UZCT,W,WMAX,WT,WTSO,WTSOC,
      5  X,XN,XR,XRS,XR2,XS,XS2,XSECB,XSO,Y,YN,Z,ZN,ZP,ZR,ZS
       DIMENSION BSCN(30),BSCN2(30),BSFN(30),BSFN2(30),CPH(360),
      1  EB(25),EBSC(30),EBSC2(30),ESO(30),EXC(899),PCS(404),SPH(360),
      2  SURV(899),TESC(30,30),TESC2(30,30),TSFN(30,30),TSFN2(30,30),
      3  TS1N(30,30),TS1N2(30,30),UT(899),WTSO(30),WTSOC(30),
      4  XSECB(25,4),XSO(80),ZP(30)
       CALL RANDC(IRC,RAN)
       IRA=IRC
       X=XSO(NXSO)
       Z=0.0
       Y=0.0
       SUZ=STHO
       UZ=CTHO
       UX=STHO*CPHO
       UY=STHO*SPHO
       CALL RANDA(IRA,RAN)
       DO 4 NESO=1,NESX
       IF(WTSOC(NESO)-RAN)4,4,2
     2 W=0.511/ESO(NESO)
       GO TO 6
     4 CONTINUE
     6 WT=1.0
       NE=1000.0/((0.511/W)+1.0)-90.0
       N=0
10     CALL RANDA(IRA,RAN)
       S=-ELOG(RAN)/UT(NE)
       XN=X+S*UX
       YN=Y+S*UY
       ZN=Z+S*UZ
       CALL CHECK3
       X=XN
       Y=YN
       Z=ZN
       IF(NSCT) 70,10,20
20     N=N+1
       IF(N-NMAX) 30,30,90
30     NE=NE
       WT=WT*SURV(NE)
       IF(NE-404) 40,40,60
40     CALL RANDA(IRA,RAN)
       IF(RAN-PCS(NE)) 60,50,50
50     WT=WT*2.0
       CALL RANDA(IRA,RAN)
       UZ=-1.0+RAN*2.0
       SUZ=SQRT(1.0-UZ**2)
       CALL RANDA(IRA,RAN)
```

```
      NPH=360.0*RAN
      UX=SUZ*CPH(NPH+1)
      UY=SUZ*SPH(NPH+1)
      W=1.0
      NE=571
      GO TO 10
60    CALL COMPT3
      IF(W-WMAX) 10,90,90
70    IF(N-NMIN) 90,80,80
80    CALL GRADE3
90    RETURN
      END
```

```
$       FASTRAN
C      SUBROUTINE CHECK3                         7-18-67
       SUBROUTINE CHECK3
       COMMON BSCN,BSCN2,BSFN,BSFN2,CPH,CPHO,CTHO,DEN,EB,EBSC,EBSC2,
     1  EMIN,ESO,EXC,FNDAX,IHIX,IHPP,IRA,IRC,LOOP,MXAX,NDAX,NE,NESO,
     2  NESX,NMAX,NMIN,NPAX,NRAN,NSCT,NXSO,NXSX,PCS,PHO,RAN,S,SPH,
     3  SPHO,STHO,SURV,SUZ,TESC,TESC2,TFEX,TFEX2,TF2N,TF2N2,TSFN,TSFN2,
     4  TS1N,TS1N2,TS2N,TS2N2,UT,UX,UY,UZ,UZCT,W,WMAX,WT,WTSO,WTSOC,
     5  X,XN,XR,XRS,XR2,XS,XS2,XSECB,XSO,Y,YN,Z,ZN,ZP,ZR,ZS
       DIMENSION BSCN(30),BSCN2(30),BSFN(30),BSFN2(30),CPH(360),
     1  EB(25),EBSC(30),EBSC2(30),ESO(30),EXC(899),PCS(404),SPH(360),
     2  SURV(899),TESC(30,30),TESC2(30,30),TSFN(30,30),TSFN2(30,30),
     3  TS1N(30,30),TS1N2(30,30),UT(899),WTSO(30),WTSOC(30),
     4  XSECB(25,4),XSO(80),ZP(30)
       IF(UX)10,290,20
    10 XN=-XN
       PUX=-UX
       GO TO 30
    20 PUX=UX
    30 IF(ZN-ZR)40,280,280
    40 IF(ZN)230,230,50
    50 IF(ZN-ZS)210,170,60
    60 IF(XN+XS)140,70,70
    70 IF(XN-XS)80,100,130
    80 ZN=ZN+UZ*(XS-XN)/PUX
       XN=XS
       IF(ZN-ZR)90,120,120
    90 IF(ZN-ZS)110,100,100
   100 NSCT=0
       GO TO 360
   110 XN=XN-PUX*(ZN-ZS)/UZ
       ZN=ZS
       GO TO 100
   120 XN=XN-PUX*(ZN-ZR)/UZ
       ZN=ZR
       NSCT=-1
       GO TO 360
   130 IF(XN-XR)140,150,160
   140 NSCT=1
       GO TO 360
   150 XN=-XR
       GO TO 140
   160 XN=XN-XR2
       IF(XN-XR)60,150,160
   170 IF(XN-XR)190,150,180
   180 XN=XN-XR2
       GO TO 170
   190 IF(XN-XS)200,100,140
   200 IF(XN+XS)140,100,100
   210 IF(XN-XR)140,150,220
   220 XN=XN-XR2
       GO TO 210
   230 XN=XN-PUX*ZN/UZ
       ZN=0.0
   240 IF(XN-XR)270,260,250
```

```
250 XN=XN-XR2
    GO TO 240
260 XN=0.99999*XN
270 NSCT=-1
    GO TO 360
280 XN=XN-PUX*(ZN-ZR)/UZ
    ZN=ZR
    GO TO 240
290 IF(UZ)340,300,300
300 IF(ABSF(XN)-XS)310,310,330
310 IF(ZN-ZS)140,320,320
320 ZN=ZR
    NSCT=-1
    GO TO 380
330 IF(ZN-ZR)140,320,320
340 IF(ZN)350,350,140
350 ZN=0.0
    NSCT=-1
    GO TO 380
360 IF(UX)370,380,380
370 XN=-XN
380 RETURN
    END
```

```
$      FASTRAN
C      SUBROUTINE COMPT3                        6-7-67
C      SAMPLE NEW DIRECTION AND ENERGY FROM COMPTON DISTRIBUTION
       SUBROUTINE COMPT3
       COMMON BSCN,BSCN2,BSFN,BSFN2,CPH,CPHO,CTHO,DEN,EB,EBSC,EBSC2,
     1  EMIN,ESO,EXC,FNDAX,IHIX,IHPP,IRA,IRC,LOOP,MXAX,NDAX,NE,NESO,
     2  NESX,NMAX,NMIN,NPAX,NRAN,NSCT,NXSO,NXSX,PCS,PHO,RAN,S,SPH,
     3  SPHO,STHO,SURV,SUZ,TESC,TESC2,TFEX,TFEX2,TF2N,TF2N2,TSFN,TSFN2,
     4  TS1N,TS1N2,TS2N,TS2N2,UT,UX,UY,UZ,UZCT,W,WMAX,WT,WTSO,WTSOG,
     5  X,XN,XR,XRS,XR2,XS,XS2,XSECB,XSO,Y,YN,Z,ZN,ZP,ZR,ZS
       DIMENSION BSCN(30),BSCN2(30),BSFN(30),BSFN2(30),CPH(360),
     1  EB(25),EBSC(30),EBSC2(30),ESO(30),EXC(899),PCS(404),SPH(360),
     2  SURV(899),TESC(30,30),TESC2(30,30),TSFN(30,30),TSFN2(30,30),
     3  TS1N(30,30),TS1N2(30,30),UT(899),WTSO(30),WTSOG(30),
     4  XSECB(25,4),XSO(80),ZP(80)
    10 CALL RANDA(IRA,RAN)
       T=2.0/W
       IF(RAN-(1.0+T)/(9.0+T))20,20,30
    20 CALL RANDA(IRA,RAN)
       R=1.0+RAN*T
       CALL RANDA(IRA,RAN)
       IF(RAN-4.0*(R-1.0)/(R**2))40,40,10
    30 CALL RANDA(IRA,RAN)
       R=(1.0+T)/(1.0+RAN*T)
       CALL RANDA(IRA,RAN)
       IF(RAN-0.5*((W-R*W+1.0)**2+1.0/R))40,40,10
    40 WN=W*R
       COM=1.0+W-WN
       W=WN
       IF(W-WMAX) 45,80,80
    45 SOM=SQRT(1.0-COM**2)
       NE=1000.0/((0.511/W)+1.0)-90.0
       CALL RANDA(IRA,RAN)
       IPH=360.0*RAN
       UZN=UZ*COM+SUZ*SOM*CPH(IPH+1)
       SUZN=SQRT(1.0-UZN**2)
       A=SUZ*SUZN
       IF(A-0.000001)50,50,60
    50 UXN=-CPH(IPH+1)*SUZN
       UYN=SPH(IPH+1)*SUZN
       GO TO 70
    60 CDPH=(COM-UZ*UZN)/A
       SDPH=SOM*SPH(IPH+1)/SUZN
       UXN=((UX*CDPH-UY*SDPH)*SUZN)/SUZ
       UYN=((UY*CDPH+UX*SDPH)*SUZN)/SUZ
    70 UX=UXN
       UY=UYN
       UZ=UZN
       SUZ=SUZN
    80 RETURN
       END
```

```
$       FASTRAN
C       SUBROUTINE GRADE3                    6-7-67
        SUBROUTINE GRADE3
        COMMON BSCN,BSCN2,BSFN,BSFN2,CPH,CPHO,CTHO,DEN,EB,EBSC,EBSC2,
       1 EMIN,ESO,EXC,FNDAX,IHIX,IHPP,IRA,IRC,LOOP,MXAX,NDAX,NE,NESO,
       2 NESX,NMAX,NMIN,NPAX,NRAN,NSCT,NXSO,NXSX,PCS,PHO,RAN,S,SPH,
       3 SPHO,STHO,SURV,SUZ,TESC,TESC2,TFEX,TFEX2,TF2N,TF2N2,TSFN,TSFN2,
       4 TS1N,TS1N2,TS2N,TS2N2,UT,UX,UY,UZ,UZCT,W,WMAX,WT,WTSO,WTSOC,
       5 X,XN,XR,XRS,XR2,XS,XS2,XSECB,XSO,Y,YN,Z,ZN,ZP,ZR,ZS
        DIMENSION BSCN(30),BSCN2(30),BSFN(30),BSFN2(30),CPH(360),
       1 EB(25),EBSC(30),EBSC2(30),ESO(30),EXC(899),PCS(404),SPH(360),
       2 SURV(899),TESC(30,30),TESC2(30,30),TSFN(30,30),TSFN2(30,30),
       3 TS1N(30,30),TS1N2(30,30),UT(899),WTSO(30),WTSOC(30),
       4 XSECB(25,4),XSO(80),ZP(30)
        IF(UZ)10,10,20
   10   ND=(X+XR)*FNDAX/XR2
        XFN=-WT/UZ
        EX=EXC(NE)*XFN
        BSCN(ND+1)=BSCN(ND+1)+WT
        BSCN2(ND+1)=BSCN2(ND+1)+WT**2
        BSFN(ND+1)=BSFN(ND+1)+XFN
        BSFN2(ND+1)=BSFN2(ND+1)+XFN**2
        EBSC(ND+1)=EBSC(ND+1)+EX
        EBSC2(ND+1)=EBSC2(ND+1)+EX**2
        GO TO 140
   20   WT2=WT**2
        XFN=WT/UZ
        XFN2=XFN**2
        EX=EXC(NE)*XFN
        EX2=EX**2
        TS2N=TS2N+WT
        TS2N2=TS2N2+WT2
        TF2N=TF2N+XFN
        TF2N2=TF2N2+XFN2
        TFEX=TFEX+EX
        TFEX2=TFEX2+EX2
        IF(UZ-UZCT)140,140,25
   25   DO 130 NP=1,NPAX
        SC=(ZP(NP)-ZR)/UZ
        XT=X+UX*SC
        IF(ABSF(XT)-XR)90,30,40
   30   ND=0
        GO TO 100
   40   IF(UX)70,50,50
   50   NRW=XT/XR2
        FNRW=NRW
        XT=XT-FNRW*XR2
        IF(XT-XR)90,30,60
   60   XT=XT-XR2
        GO TO 90
   70   NRW=-XT/XR2
        FNRW=NRW
        XT=XT+FNRW*XR2
        IF(XT+XR)80,30,90
```

```
 90 ND=(XT+XR)*FNDAX/XR2
100 TS1N(ND+1,NP)=TS1N(ND+1,NP)+WT
    TS1N2(ND+1,NP)=TS1N2(ND+1,NP)+WT2
    TSFN(ND+1,NP)=TSFN(ND+1,NP)+XFN
    TSFN2(ND+1,NP)=TSFN2(ND+1,NP)+XFN2
    TESC(ND+1,NP)=TESC(ND+1,NP)+EX
    TESC2(ND+1,NP)=TESC2(ND+1,NP)+EX2
130 CONTINUE
140 RETURN
    END
```

```
$       FASTRAN
C      SUBROUTINE TEACH3                        7-26-67
       SUBROUTINE TEACH3
       COMMON BSCN,BSCN2,BSFN,BSFN2,CPH,CPHO,CTHO,DEN,EB,EBSC,EBSC2,
     1 EMIN,ESO,EXC,FNDAX,IHIX,IHPP,IRA,IRC,LOOP,MXAX,NDAX,NE,NESO,
     2 NESX,NMAX,NMIN,NPAX,NRAN,NSCT,NXSO,NXSX,PCS,PHO,RAN,S,SPH,
     3 SPHO,STHO,SURV,SUZ,TESC,TESC2,TFEX,TFEX2,TF2N,TF2N2,TSFN,TSFN2,
     4 TS1N,TS1N2,TS2N,TS2N2,UT,UX,UY,UZ,UZCT,W,WMAX,WT,WTSO,WTSOG,
     5 X,XN,XR,XRS,XR2,XS,XS2,XSEGB,XSO,Y,YN,Z,ZN,ZP,ZR,ZS
      DIMENSION BSCN(30),BSCN2(30),BSFN(30),BSFN2(30),CPH(360),
     1 EB(25),EBSC(30),EBSC2(30),ESO(30),EXC(899),PCS(404),SPH(360),
     2 SURV(899),TESC(30,30),TESC2(30,30),TSFN(30,30),TSFN2(30,30),
     3 TS1N(30,30),TS1N2(30,30),UT(899),WTSO(30),WTSOG(30),
     4 XSECB(25,4),XSO(80),ZP(30)
      DIMENSION TS3N(30),TS3N2(30),TF3N(30),TF3N2(30),TFEX3(30),
     1 TFEX32(30),XDET(30)
      HIX=IHIX
      FLOOP=LOOP
      HIX=HIX*FLOOP
      DO 40 NP=1,NPAX
      TS3N(NP)=0.0
      TS3N2(NP)=0.0
      TF3N(NP)=0.0
      TF3N2(NP)=0.0
      TFEX3(NP)=0.0
      TFEX32(NP)=0.0
      DO 10 ND=1,NDAX
      TS3N(NP)=TS3N(NP)+TS1N(ND,NP)
      TS3N2(NP)=TS3N2(NP)+TS1N2(ND,NP)
      TF3N(NP)=TF3N(NP)+TSFN(ND,NP)
      TF3N2(NP)=TF3N2(NP)+TSFN2(ND,NP)
      TFEX3(NP)=TFEX3(NP)+TESC(ND,NP)
   10 TFEX32(NP)=TFEX32(NP)+TESC2(ND,NP)
      TS3N(NP)=TS3N(NP)/HIX
      TS3N2(NP)=TS3N2(NP)/HIX
      TF3N(NP)=TF3N(NP)/HIX
      TF3N2(NP)=TF3N2(NP)/HIX
      TFEX3(NP)=TFEX3(NP)/HIX
      TFEX32(NP)=TFEX32(NP)/HIX
      IF(TS3N(NP))30,20,30
   20 TS3N2(NP)=-10.0
      TF3N2(NP)=-10.0
      TFEX32(NP)=-10.0
      GO TO 40
   30 TS3N2(NP)=SQRT((TS3N2(NP)-TS3N(NP)**2)/(HIX-1.0))/TS3N(NP)
      TF3N2(NP)=SQRT((TF3N2(NP)-TF3N(NP)**2)/(HIX-1.0))/TF3N(NP)
      TFEX32(NP) =SQRT((TFEX32(NP)-TFEX3(NP)**2)/(HIX-1.0))/TFEX3(NP)
   40 CONTINUE
      TS2N=TS2N/HIX
      TS2N2=TS2N2/HIX
      TF2N=TF2N/HIX
      TF2N2=TF2N2/HIX
      TFEX=TFEX/HIX
      TFEX2=TFEX2/HIX
      IF(TS2N)60,50,60
   50 TS2N2=-10.0
      TF2N2=-10.0
```

```
      TFEX2=-10.0
      GO TO 70
   60 TS2N2=SQRT((TS2N2-TS2N**2)/(HIX-1.0))/TS2N
      TF2N2=SQRT((TF2N2-TF2N**2)/(HIX-1.0))/TF2N
      TFEX2=SQRT((TFEX2-TFEX**2)/(HIX-1.0))/TFEX
   70 DO 130 ND=1,NDAX
      BSCN(ND)=BSCN(ND)/HIX
      BSCN2(ND)=BSCN2(ND)/HIX
      BSFN(ND)=BSFN(ND)/HIX
      BSFN2(ND)=BSFN2(ND)/HIX
      EBSC(ND)=EBSC(ND)/HIX
      EBSC2(ND)=EBSC2(ND)/HIX
      IF(BSCN(ND))90,80,90
   80 BSCN2(ND)=-10.0
      BSFN2(ND)=-10.0
      EBSC2(ND)=-10.0
      GO TO 100
   90 BSCN2(ND)=SQRT((BSCN2(ND)-BSCN(ND)**2)/(HIX-1.0))/BSCN(ND)
      BSFN2(ND)=SQRT((BSFN2(ND)-BSFN(ND)**2)/(HIX-1.0))/BSFN(ND)
      EBSC2(ND)=SQRT((EBSC2(ND)-EBSC(ND)**2)/(HIX-1.0))/EBSC(ND)
  100 DO 130 NP=1,NPAX
      TS1N(ND,NP)=TS1N(ND,NP)/HIX
      TS1N2(ND,NP)=TS1N2(ND,NP)/HIX
      TSFN(ND,NP)=TSFN(ND,NP)/HIX
      TSFN2(ND,NP)=TSFN2(ND,NP)/HIX
      TESC(ND,NP)=TESC(ND,NP)/HIX
      TESC2(ND,NP)=TESC2(ND,NP)/HIX
      IF(TS1N(ND,NP))120,110,120
  110 TS1N2(ND,NP)=-10.0
      TSFN2(ND,NP)=-10.0
      TESC2(ND,NP)=-10.0
      GO TO 130
  120 TS1N2(ND,NP)=SQRT((TS1N2(ND,NP)-TS1N(ND,NP)**2)/(HIX-1.0))
     1 /TS1N(ND,NP)
      TSFN2(ND,NP)=SQRT((TSFN2(ND,NP)-TSFN(ND,NP)**2)/(HIX-1.0))
     1 /TSFN(ND,NP)
      TESC2(ND,NP)=SQRT((TESC2(ND,NP)-TESC(ND,NP)**2)/(HIX-1.0))
     1 /TESC(ND,NP)
  130 CONTINUE
      DOSO=0.0
      DO 140 NESO=1,NESM
      NE=1000.0/(ESO(NESO)+1.0)-90.0
  140 DOSO=DOSO+EXC(NE)*WTSO(NESO)
      TF2N=TF2N*CTHO
      TFEX=TFEX*CTHO/DOSO
      DO 150 NP=1,NPAX
      TF3N(NP)=TF3N(NP)*CTHO
  150 TFEX3(NP)=TFEX3(NP)*CTHO/DOSO
      DO 160 ND=1,NDAX
      BSCN(ND)=BSCN(ND)*FNDAX
      BSFN(ND)=BSFN(ND)*FNDAX*CTHO
      EBSC(ND)=EBSC(ND)*FNDAX*CTHO/DOSO
      DO 160 NP=1,NPAX
      TS1N(ND,NP)=TS1N(ND,NP)*FNDAX
      TSFN(ND,NP)=TSFN(ND,NP)*FNDAX*CTHO
  160 TESC(ND,NP)=TESC(ND,NP)*FNDAX*CTHO/DOSO
```

```
      DO 165 NP=1,NPAX
  165 ZP(NP)=ZP(NP)-ZR
  170 FORMAT(1H0)
  175 FORMAT(1H1)
      WOT6,175
      WOT6,170
      WOT6,180,IRC
  180 FORMAT(21H FINAL RANDOM NUMBER=O13)
      WOT6,170
      WOT6,185,DOSO
  185 FORMAT(54H EXPOSURE CURRENT DUE TO UNIT INCIDENT NUMBER CURRENT=
     1  1PE10.2)
      WOT6,170
      DX=XR2/FNDAX
      XX=-DX/2.0
      DO 190 ND=1,NDAX
      XX=XX+DX
  190 XDET(ND)=XX
      WOT6,200
  200 FORMAT(32H BACKSCATTERING FROM RIBBED SLAB)
      WOT6,210
  210 FORMAT(72H NUMBER CURRENT (FLUX) NORMALIZED TO UNIT INCIDENT NUMBE
     1R CURRENT (FLUX))
      WOT6,220
  220 FORMAT(46H EXPOSURE NORMALIZED TO UNIT INCIDENT EXPOSURE)
      WOT6,170
      WOT6,230
  230 FORMAT(11H HORIZONTAL)
      WOT6,240
  240 FORMAT(31H   DETECTOR    NUMBER    NUMBER)
      WOT6,250
  250 FORMAT(41H   POSITION   CURRENT       FLUX  EXPOSURE)
      DO 260 ND=1,NDAX
  260 WOT6,270,XDET(ND),        BSCN(ND),BSFN(ND),EBSC(ND)
  270 FORMAT(F11.3,1P10E10.2)
      WOT6,175
      WOT6,170
      WOT6,280
  280 FORMAT(64H FRACTIONAL STATISTICAL DEVIATION OF RESULTS IN PRECEEDI
     1NG TABLE)
      WOT6,170
      WOT6,230
      WOT6,240
      WOT6,250
      DO 290 ND=1,NDAX
  290 WOT6,300,XDET(ND),BSCN2(ND),BSFN2(ND),EBSC2(ND)
  300 FORMAT(F11.3,10F10.4)
      WOT6,175
      WOT6,170
      WOT6,310
  310 FORMAT(56H TRANSMISSION AVERAGED OVER ALL DETECTORS IN GIVEN PLANE
     1)
      WOT6,320
  320 FORMAT(17H NO COSINE CUTOFF)
      WOT6,330
  330 FORMAT(48H RESULTS NORMALIZED AS IN CASE OF BACKSCATTERING)
```

```
      WOT6,170
      WOT6,340
  340 FORMAT(37H                                FRACTIONAL)
      WOT6,350
  350 FORMAT(37H                            RESULT   DEVIATION)
      WOT6,360,TS2N,TS2N2
  360 FORMAT(16H NUMBER CURRENT 1PE10.2,0PF10.4)
      WOT6,370,TF2N,TF2N2
  370 FORMAT(16H    NUMBER FLUX 1PE10.2,0PF10.4)
      WOT6,380,TFEX,TFEX2
  380 FORMAT(16H       EXPOSURE 1PE10.2,0PF10.4)
      WOT6,175
      WOT6,170
      WOT6,310
      WOT6,390,UZCT
  390 FORMAT(15H COSINE CUTOFF=F9.5)
      WOT6,330
      WOT6,170
      WOT6,400
  400 FORMAT(11H  HEIGHT OF)
      WOT6,410
  410 FORMAT(11H   DETECTOR)
      WOT6,420
  420 FORMAT(31H      PLANE     NUMBER     NUMBER)
      WOT6,430
  430 FORMAT(41H  ABOVE RIB   CURRENT       FLUX   EXPOSURE)
      DO 440 NP=1,NPAX
  440 WOT6,270,ZP(NP),TS3N(NP),TF3N(NP),TFEX3(NP)
      WOT6,175
      WOT6,170
      WOT6,280
      WOT6,170
      WOT6,400
      WOT6,410
      WOT6,420
      WOT6,430
      DO 450 NP=1,NPAX
  450 WOT6,300,ZP(NP),TS3N2(NP),TF3N2(NP),TFEX32(NP)
      WOT6,175
      WOT6,170
      WOT6,460
  460 FORMAT(100H IN THE TABLES WHICH FOLLOW, H= HEIGHT OF DETECTOR PLAN
     1E ABOVE RIB, X= POSITION OF DETECTOR IN PLANE)
      WOT6,170
      WOT6,470,UZCT
  470 FORMAT(43H TRANSMITTED NUMBER CURRENT, COSINE CUTOFF=F9.5)
      WOT6,480
  480 FORMAT(43H NORMALIZED TO UNIT INCIDENT NUMBER CURRENT)
      CALL RIBTAB(NPAX,NDAX,ZP,XDET,TS1N)
      WOT6,175
      WOT6,170
      WOT6,280
      CALL RIBTAB(NPAX,NDAX,ZP,XDET,TS1N2)
      WOT6,175
      WOT6,170
      WOT6,490,UZCT
```

```
  490 FORMAT(40H TRANSMITTED NUMBER FLUX, COSINE CUTOFF=F9.5)
      WOT6,500
  500 FORMAT(40H NORMALIZED TO UNIT INCIDENT NUMBER FLUX)
      CALL RIBTAB(NPAX,NDAX,ZP,XDET,TSFN)
      WOT6,175
      WOT6,170
      WOT6,280
      CALL RIBTAB(NPAX,NDAX,ZP,XDET,TSFN2)
      WOT6,175
      WOT6,170
      WOT6,510,UZGT
  510 FORMAT(64H EXPOSURE DUE TO TRANSMITTED SCATTERED RADIATION, COSINE
     1 CUTOFF=F9.5)
      WOT6,520
  520 FORMAT(54H NORMALIZED TO UNIT EXPOSURE DUE TO INCIDENT RADIATION)
      CALL RIBTAB(NPAX,NDAX,ZP,XDET,TESC)
      WOT6,175
      WOT6,170
      WOT6,280
      CALL RIBTAB(NPAX,NDAX,ZP,XDET,TESC2)
      WOT6,175
      WOT5,530,(ZP(NP),NP=1,NPAX)
  530 FORMAT(1P7E10.3)
      WOT5,530,(XDET(ND),ND=1,NDAX)
      WOT5,530,((TESC (ND,NP),ND=1,NDAX),NP=1,NPAX)
      WOT5,530,((TESC2(ND,NP),ND=1,NDAX),NP=1,NPAX)
      NTABIN=1
      DO 540 NP=1,NPAX
      ZT=ZP(NP)+ZR
      DO 540 ND=1,NDAX
      TESC2(ND,NP)=TESC2(ND,NP)*TESC(ND,NP)
      CALL DIRIB(NTABIN,EB,XSECB(1,3),MXAX,CPHO,CTHO,XR,XS,ZR,ZS,
     1  XDET(ND),ZT     ,ESO,WTSO,NESX,TSFN(ND,NP))
      TSFN(ND,NP)=TSFN(ND,NP)*CTHO
      TESC(ND,NP)=TESC(ND,NP)+TSFN(ND,NP)
  540 TESC2(ND,NP)=TESC2(ND,NP)/TESC(ND,NP)
      WOT6,170
      WOT6,550
  550 FORMAT(38H EXPOSURE DUE TO UNSCATTERED RADIATION)
      WOT6,520
      CALL RIBTAB(NPAX,NDAX,ZP,XDET,TSFN)
      WOT6,175
      WOT6,170
      WOT6,560,UZGT
  560 FORMAT(54H EXPOSURE (SCATTERED PLUS UNSCATTERED), COSINE CUTOFF=
     1  F9.5)
      WOT6,520
      CALL RIBTAB(NPAX,NDAX,ZP,XDET,TESC)
      WOT6,175
      WOT6,170
      WOT6,280
      CALL RIBTAB(NPAX,NDAX,ZP,XDET,TESC2)
      WOT6,175
      WOT5,530,((TESC (ND,NP),ND=1,NDAX),NP=1,NPAX)
      RETURN
      END
```

```
$       FASTRAN
C       SUBROUTINE DIRIB                         7-1-67
        SUBROUTINE DIRIB(NTABIN,EB,XSECB,MXAX,CPHO,CTHO,XR,XS,ZR,ZS,XD,ZP,
       1 ESO,WTSO,NESO,DIR)
        DIMENSION EB(25),XSECB(25,2),ESO(30),WTSO(30),UAT(30),UEN(30),
       1 XSEC(2)
        UX=CPHO*SQRT(1.0-CTHO**2)
        IF(UX)10,20,20
   10   UX=-UX
        X=XR-XD
        GO TO 30
   20   X=XD-XR
   30   T=0.0
        ZT=ZR
        X=X-UX*(ZP-ZR)/CTHO
   40   IF(ABSF(X)-XR)70,60,50
   50   X=X+2.0*XR
        GO TO 40
   60   X=XR
   70   IF(ABSF(X)-XS)130,80,80
   80   IF(X-XS)90,130,100
   90   X=X+2.0*XR
  100   XT=X-UX*(ZT-ZS)/CTHO
        IF(XT-XS)120,110,110
  110   T=T+ZT/CTHO
        GO TO 160
  120   S=(X-XS)/UX
        T=T+S
        ZT=ZT-CTHO*S
        X=XS
  130   XT=X-UX*(ZT-ZS)/CTHO
        IF(XT+XS)150,140,140
  140   T=T+ZS/CTHO
        GO TO 160
  150   ZT=ZT-CTHO*(X+XS)/UX
        X=2.0*XR-XS
        GO TO 100
  160   GO TO (170,190),NTABIN
  170   DNORM=0.0
        DO 180 NES=1,NESO
        EL=ELOG(ESO(NES))
        CALL TABIN(NTABIN,XSECB,EB,MXAX,2,EL,XSEC)
        UAT(NES)=EXP(XSEC(1))
        UEN(NES)=EXP(XSEC(2)+EL)
  180   DNORM=DNORM+WTSO(NES)*UEN(NES)
  190   DIR=0.0
        DO 200 NES=1,NESO
  200   DIR=DIR+WTSO(NES)*UEN(NES)*EXP(-UAT(NES)*T)
        DIR=DIR/(DNORM*CTHO)
        RETURN
        END
```

```
C       SUBROUTINE RIBTAB                         5-22-67
        SUBROUTINE RIBTAB(NZAX,NXAX,Z,X,A)
        DIMENSION Z(30),X(30),A(30,30)
        WOT6,10
     10 FORMAT(1H0)
        IF(NZAX-10)30,20,20
     20 NZT=10
        GO TO 40
     30 NZT=NZAX
     40 NZB=1
     50 WOT6,60,(Z(NZ),NZ=NZB,NZT)
     60 FORMAT(12H          X, H=F7.3,9F10.3)
        DO 70 NX=1,NXAX
     70 WOT6,80,X(NX),(A(NX,NZ),NZ=NZB,NZT)
     80 FORMAT(F10.3,1P10E10.2)
        WOT6,10
        IF(NZT-NZAX)90,110,110
     90 NZB=NZT+1
        NZT=NZT+10
        IF(NZT-NZAX)50,50,100
    100 NZT=NZAX
        GO TO 50
    110 RETURN
        END
```

```
$        FASTRAN
C       SUBROUTINE TABIN                         28-8-64
        SUBROUTINE TABIN(NTABIN,FB,XB,NMAX,MMAX,X,FX)
        DIMENSION FB(25,8),XB(25),FX(8),XBAV(25),D1(25),D2(25)
        GO TO (10,30),NTABIN
   10   NMAX1=NMAX-1
        DO 20 N=2,NMAX1
        XBAV(N)=(XB(N-1)+XB(N))/2.0
        D1(N)=(XB(N-1)-XB(N))*(XB(N-1)-XB(N+1))
   20   D2(N)=(XB(N)-XB(N-1))*(XB(N)-XB(N+1))
        NTABIN=2
        NEXS=NMAX1-2
   30   IF(X-XB(1))60,50,40
   40   NX=2
        GO TO 200
   50   NX=1
        GO TO 220
   60   IF(X-XB(2))80,70,40
   70   NX=2
        GO TO 220
   80   IF(NEXS)90,110,140
   90   WOT6,100
  100   FORMAT(33HONOT ENOUGH BASE POINTS FOR TABIN)
        CALL SYSTEM
  110   IF(X-XB(NMAX))130,120,130
  120   NX=NMAX
        GO TO 220
  130   NX=NMAX1
        GO TO 200
  140   DO 170 N=3,NMAX1
        IF(X-XB(N))170,150,160
  150   NX=N
        GO TO 220
  160   NX=N
        GO TO 180
  170   CONTINUE
        GO TO 110
  180   IF(X-XBAV(NX))200,200,190
  190   NX=NX-1
  200   WT1=(X-XB(NX))*(X-XB(NX+1))/D1(NX)
        WT2=(X-XB(NX-1))*(X-XB(NX+1))/D2(NX)
        WT3=1.0-WT1-WT2
        DO 210 M=1,MMAX
  210   FX(M)=WT1*FB(NX-1,M)+WT2*FB(NX,M)+WT3*FB(NX+1,M)
        RETURN
  220   DO 230 M=1,MMAX
  230   FX(M)=FB(NX,M)
        RETURN
        END
```

```
$       SCATRE,PUNCH OBJECT
        REM      CALL RAND A,B,C,D (IR,R)
        REM      FIRST DIGIT OF IR LESS OR EQUAL 3 OCTAL
        REM      LAST DIGIT OF IR EQUAL 1 BINARY
        REM      AT LEAST 7 DIGITS TO EXPRESS IR IN OCTAL
        ENTRY    RANDA
        ENTRY    RANDB
        ENTRY    RANDC
        ENTRY    RANDD
 RANDA  CLA      MULT
        TRA      *+6
 RANDB  CLA      MULT+1
        TRA      *+4
 RANDC  CLA      MULT+2
        TRA      *+2
 RANDD  CLA      MULT+3
        STO      TEMP
        LDQ*     1,4
        MPY      TEMP
        STQ*     1,4
        PXD      0,0
        LLS      27
        ADD      *+4
        FAD      *+3
        STO*     2,4
        TRA      3,4
        OCT      200000000000
  MULT  OCT      343277244615
        OCT      011060471625
        OCT      000272207335
        OCT      000007346545
  TEMP  BSS      1
        END
```

```
                         PROCESSED BY HAVOC OF 04/01/67

L106     07/29/67             9 20 19.9 PM         L106      68004****L106
      E E MORRIS              035 035 C050 0025 0100NUCE          L106 003
      $       GO
      $       BINARY
      $       DATA

MAP
      SYSTEM 00000*     SYSWOT C0000*     (MAIN) 10000     LEARN3 10052     DATEX3 11201     TRACK3 12011
      CHECK3 12313      COMPT3 12612      GRADE3 13166     TEACH3 13522     DIRIB  17042     RIBTAB 17606
      TABIN  20006      RANCA  20526      RANDC  20545     .EXIT  20555*    EXP    20613*    SORT   20714*
      .ERR   20777*     .ATLOC 20777*     .EOEP  21070*    .ITEEP 21070*    .IOCTU 21166*    .CTN   21206*
      (CCER) 21207*     ATLOC  21234*     .EOTC  21261*    (STH)  21305*    SIN    21546*    COS    21546*
      ELCC   21726*     (TSH)  22070*     .RDR.  22271*    .BCDC  22434*    .IOH   22434*    .IOHRT 22434*
      (RTN)  22434*     (FIL)  22434*     (PROG) 25532     (ERAS) 54375     (SUBT) 72423
26643 LOCS. CAN BE SAFELY USED IN EXPANDING PROG. (OCTAL)

 ADAM RIB II RUN 15, RIBBED SLAB, PLANE CO-60 SOURCE, 7-26-67

 IHIX  NPAX  NDAX  NMAX  NMIN  MXAX  NXSX  NESX  LOOP
10000   10    20    50     1    25    40    13    10

INITIAL RANDOM NUMBER
233206121545

    XS       YR       ZS       ZR
  4.125    6.125    4.000   10.000

DETECTOR PLANE HEIGHTS (MEASURED FROM ENTRANCE FACE OF SLAB)
 10.000  16.000  22.000  28.000  40.000  52.000  64.000  76.000 100.000
124.000

COSINE CUTOFF FOR FLUX COMPUTATION
   .010

COSINE OF ANGLE OF INCIDENCE
  1.000

AZIMUTH OF INCIDENT BEAM
   .000

DENSITY OF SLAB AND RIBS
  6.045
```

AVERAGE ATTENUATION COEFFICIENTS FOR NBS CONCRETE(UNIT=SQUARE CM/G)

ENERGY	COMPTON	PAIR	TOTAL
.010	1.929E-01	.000E 00	2.646E 01
.015	1.895E-01	.000E 00	8.010E 00
.020	1.862E-01	.000E 00	3.446E 00
.030	1.800E-01	.000E 00	1.118E 00
.040	1.743E-01	.000E 00	5.588E-01
.050	1.691E-01	.000E 00	3.608E-01
.060	1.644E-01	.000E 00	2.734E-01
.080	1.558E-01	.000E 00	2.004E-01
.100	1.485E-01	.000E 00	1.704E-01
.150	1.336E-01	.000E 00	1.398E-01
.200	1.225E-01	.000E 00	1.250E-01
.300	1.065E-01	.000E 00	1.072E-01
.400	9.539E-02	.000E 00	9.572E-02
.500	8.711E-02	.000E 00	8.729E-02
.600	8.058E-02	.000E 00	[illegible].069E-02
.800	7.078E-02	.000E 00	7.083E-02
1.000	6.362E-02	.000E 00	6.366E-02
1.500	5.168E-02	1.548E-04	5.185E-02
2.000	4.410E-02	6.287E-04	4.474E-02
3.000	3.467E-02	1.788E-03	3.647E-02
4.000	2.899E-02	2.921E-03	3.191E-02
5.000	2.503E-02	3.9[illegible]6E-03	2.897E-02
6.000	2.212E-02	4.852E-03	2.698E-02
8.000	1.810E-02	6.413E-03	2.451E-02
10.000	1.541E-02	7.709E-03	2.312E-02

```
ENERGY ABSORPTION COEFFICIENTS FOR AIR

 .010 4.610E 00
 .015 1.270E 00
 .020 5.110E-01
 .030 1.480E-01
 .040 6.680E-02
 .050 4.060E-02
 .060 3.050E-02
 .080 2.430E-02
 .100 2.340E-02
 .150 2.500E-02
 .200 2.680E-02
 .300 2.870E-02
 .400 2.950E-02
 .500 2.960E-02
 .600 2.950E-02
 .800 2.890E-02
 1.000 2.780E-02
 1.500 2.540E-02
 2.000 2.340E-02
 3.000 2.050E-02
 4.000 1.860E-02
 5.000 1.740E-02
 6.000 1.640E-02
 8.000 1.520E-02
10.000 1.450E-02

CUTOFF ENERGY
  .040

SOURCE ENERGIES
  1.330   1.250   1.170   1.050    .950    .850    .750    .650    .550
   .450    .350    .250    .150

SOURCE ENERGY WEIGHTS
 4.26E-01  1.78E-02  4.06E-01  4.01E-02  1.84E-02  1.48E-02  1.34E-02
 1.48E-02  1.73E-02  1.35E-02  1.17E-02  5.44E-03  1.71E-05
```

FINAL RANDOM NUMBER= 213612440745

EXPOSURE CURRENT DUE TO UNIT INCIDENT NUMBER CURRENT= 3.14E-02

BACKSCATTERING FROM RIBBED SLAB
NUMBER CURRENT (FLUX) NORMALIZED TO UNIT INCIDENT NUMBER CURRENT (FLUX)
EXPOSURE NORMALIZED TO UNIT INCIDENT EXPOSURE

HORIZONTAL DETECTOR POSITION	NUMBER CURRENT	NUMBER FLUX	EXPOSURE
.306	2.01E-01	4.05E-01	7.22E-02
.919	2.05E-01	4.05E-01	6.80E-02
1.531	2.02E-01	3.92E-01	7.21E-02
2.144	2.03E-01	4.14E-01	7.01E-02
2.756	2.06E-01	4.12E-01	7.54E-02
3.369	2.09E-01	4.39E-01	7.93E-02
3.981	1.85E-01	3.65E-01	6.51E-02
4.594	1.99E-01	4.01E-01	7.06E-02
5.206	2.03E-01	4.00E-01	7.08E-02
5.819	2.01E-01	4.18E-01	7.48E-02
6.431	2.06E-01	4.22E-01	7.88E-02
7.044	1.99E-01	3.73E-01	6.41E-02
7.656	1.98E-01	4.11E-01	7.47E-02
8.269	1.92E-01	3.80E-01	6.89E-02
8.881	1.97E-01	4.06E-01	7.54E-02
9.494	1.87E-01	3.55E-01	6.20E-02
10.106	1.98E-01	4.05E-01	7.41E-02
10.719	2.01E-01	3.93E-01	6.99E-02
11.331	2.04E-01	3.91E-01	6.83E-02
11.944	2.01E-01	3.87E-01	6.80E-02

FRACTIONAL STATISTICAL DEVIATION OF RESULTS IN PRECEEDING TABLE

HORIZONTAL DETECTOR POSITION	NUMBER CURRENT	NUMBER FLUX	EXPOSURE
.306	.0302	.0419	.0521
.919	.0299	.0475	.0500
1.531	.0303	.0425	.0508
2.144	.0301	.0746	.0578
2.756	.0299	.0575	.0951
3.369	.0297	.0483	.0661
3.981	.0316	.0419	.0499
4.594	.0304	.0531	.0559
5.206	.0301	.0393	.0487
5.819	.0304	.0579	.0632
6.431	.0298	.0473	.0685
7.044	.0305	.0405	.0471
7.656	.0306	.0518	.0625
8.269	.0310	.0440	.0562
8.881	.0306	.0521	.0723
9.494	.0315	.0411	.0483
10.106	.0306	.0518	.0659
10.719	.0303	.0392	.0482
11.331	.0300	.0394	.0511
11.944	.0304	.0419	.0521

TRANSMISSION AVERAGED OVER ALL DETECTORS IN GIVEN PLANE
NO COSINE CUTOFF
RESULTS NORMALIZED AS IN CASE OF BACKSCATTERING

	RESULT	FRACTIONAL DEVIATION
NUMBER CURRENT	2.68[illegible]-01	.0051
NUMBER FLUX	4.17[illegible]-01	.0124
EXPOSURE	1.85[illegible]-01	.0088

TRANSMISSION AVERAGED OVER ALL DETECTORS IN GIVEN PLANE
COSINE CUTOFF= .01000
RESULTS NORMALIZED AS IN CASE OF BACKSCATTERING

HEIGHT OF DETECTOR PLANE ABOVE RIB	NUMBER CURRENT	NUMBER FLUX	EXPOSURE
.000	2.68E-01	4.11E-01	1.84E-01
6.000	2.68E-01	4.11E-01	1.84E-01
12.000	2.68E-01	4.11E-01	1.84E-01
18.000	2.68E-01	4.11E-01	1.84E-01
30.000	2.68E-01	4.11E-01	1.84E-01
42.000	2.68E-01	4.11E-01	1.84E-01
54.000	2.68E-01	4.11E-01	1.84E-01
66.000	2.68E-01	4.11E-01	1.84E-01
90.000	2.68E-01	4.11E-01	1.84E-01
114.000	2.68E-01	4.11E-01	1.84E-01

FRACTICNAL STATISTICAL DEVIATION OF RESULTS IN PRECEEDING TABLE

HEIGHT OF DETECTOR PLANE ABOVE RIB	NUMBER CURRENT	NUMBER FLUX	EXPOSURE
.00C	.0C51	.C068	.0066
6.C00	.CC51	.C068	.C066
12.C00	.0051	.CC68	.0066
18.C00	.CC51	.C068	.G066
30.C00	.CC51	.C068	.C066
42.C0C	.CC51	.C068	.0066
54.C00	.C051	.C068	.0066
66.C0C	.0C51	.C068	.0066
90.C00	.CC51	.C068	.0066
114.C0C	.CC51	.0068	.0066

IN THE TABLES WHICH FOLLOW, H= HEIGHT OF DETECTOR PLANE ABOVE RIB, X= POSITION OF DETECTOR IN PLANE

TRANSMITTED NUMBER CURRENT, COSINE CUTOFF= .C1000
NORMALIZED TO UNIT INCIDENT NUMBER CURRENT

X, H=	.CCC	6.CCO	12.000	18.CCO	30.CCO	42.000	54.000	66.000	90.000	114.000
.3C6	1.54E-01	2.50E-01	2.68E-01	2.67E-01	2.77E-01	2.67E-01	2.81E-01	2.68E-01	2.61E-01	2.60E-01
.919	1.52E-01	2.49E-01	2.67E-01	2.59E-01	2.61E-01	2.66E-01	2.61E-01	2.80E-01	2.75E-01	2.77E-01
1.531	1.87E-01	2.67E-01	2.70E-01	2.61E-01	2.63E-01	2.75E-01	2.58E-01	2.67E-01	2.60E-01	2.80E-01
2.144	2.59E-01	2.63E-01	2.77E-01	2.71E-01	2.70E-01	2.64E-01	2.71E-01	2.65E-01	2.55E-01	2.82E-01
2.756	[illegible]	2.71E-01	2.62E-01	2.63E-01	2.64E-01	2.68E-01	2.61E-01	2.56E-01	2.69E-01	2.73E-01
3.369	3.18E-01	2.60E-01	2.77E-01	2.70E-01	2.68E-01	2.57E-01	2.62E-01	2.71E-01	2.61E-01	2.72E-01
3.981	3.07E-01	2.66E-01	2.76E-01	2.69E-01	2.86E-01	2.72E-01	2.70E-01	2.65E-01	2.64E-01	2.72E-01
4.594	3.16E-01	2.73E-01	2.65E-01	2.58E-01	2.67E-01	2.60E-01	2.68E-01	2.66E-01	2.76E-01	2.59E-01
5.206	3.41E-01	2.73E-01	2.67E-01	2.66E-01	2.66E-01	2.75E-01	2.73E-01	2.66E-01	2.75E-01	2.71E-01
5.819	3.30E-01	2.74E-01	2.67E-01	2.65E-01	2.67E-01	2.76E-01	2.57E-01	2.69E-01	2.65E-01	2.70E-01
6.431	3.32E-01	2.95E-01	2.84E-01	2.82E-01	2.68E-01	2.78E-01	2.70E-01	2.60E-01	2.66E-01	2.71E-01
7.044	3.32E-01	2.71E-01	2.63E-01	2.68E-01	2.61E-01	2.75E-01	2.68E-01	2.54E-01	2.74E-01	2.71E-01
7.656	3.18E-01	2.62E-01	2.62E-01	2.63E-01	2.70E-01	2.77E-01	2.67E-01	2.70E-01	2.74E-01	2.58E-01
8.269	3.20E-01	2.73E-01	2.64E-01	2.72E-01	2.80E-01	2.73E-01	2.65E-01	2.71E-01	2.75E-01	2.66E-01
8.881	3.24E-01	2.85E-01	2.64E-01	2.60E-01	2.72E-01	2.62E-01	2.76E-01	2.67E-01	2.63E-01	2.63E-01
9.494	2.84E-01	2.65E-01	2.69E-01	2.71E-01	2.63E-01	2.59E-01	2.72E-01	2.71E-01	2.65E-01	2.63E-01
10.106	2.66E-01	2.69E-01	2.68E-01	2.77E-01	2.51E-01	2.76E-01	2.74E-01	2.86E-01	2.72E-01	2.68E-01
10.719	1.84E-01	2.53E-01	2.57E-01	2.62E-01	2.71E-01	2.63E-01	2.69E-01	2.61E-01	2.67E-01	2.73E-01
11.331	1.66E-01	2.51E-01	2.73E-01	2.74E-01	2.62E-01	2.57E-01	2.70E-01	2.65E-01	2.74E-01	2.55E-01
11.944	1.55E-01	2.65E-01	2.58E-01	2.69E-01	2.70E-01	2.58E-01	2.64E-01	2.80E-01	2.66E-01	2.54E-01

FRACTIONAL STATISTICAL DEVIATION OF RESULTS IN PRECEEDING TABLE

X, H=	.000	6.000	12.000	18.000	30.000	42.000	54.000	66.000	90.000	114.000
.306	3.51E-02	2.75E-02	2.66E-02	2.66E-02	2.61E-02	2.66E-02	2.59E-02	2.65E-02	2.68E-02	2.70E-02
.919	3.43E-02	2.75E-02	2.65E-02	2.70E-02	2.68E-02	2.66E-02	2.70E-02	2.60E-02	2.62E-02	2.61E-02
1.531	3.19E-02	2.66E-02	2.64E-02	2.69E-02	2.68E-02	2.62E-02	2.71E-02	2.65E-02	2.69E-02	2.60E-02
2.144	2.70E-02	2.68E-02	2.61E-02	2.64E-02	2.64E-02	2.67E-02	2.65E-02	2.67E-02	2.72E-02	2.59E-02
2.756	2.49E-02	2.64E-02	2.68E-02	2.68E-02	2.68E-02	2.65E-02	2.69E-02	2.72E-02	2.65E-02	2.63E-02
3.369	2.43E-02	2.69E-02	2.61E-02	2.64E-02	2.65E-02	2.72E-02	2.69E-02	2.63E-02	2.68E-02	2.64E-02
3.981	2.47E-02	2.57E-02	2.62E-02	2.65E-02	2.56E-02	2.64E-02	2.64E-02	2.67E-02	2.67E-02	2.62E-02
4.594	2.44E-02	2.64E-02	2.67E-02	2.66E-02	2.66E-02	2.70E-02	2.65E-02	2.66E-02	2.61E-02	2.70E-02
5.206	2.35E-02	2.63E-02	2.66E-02	2.67E-02	2.67E-02	2.61E-02	2.63E-02	2.67E-02	2.62E-02	2.64E-02
5.819	2.38E-02	2.62E-02	2.67E-02	2.66E-02	2.66E-02	2.62E-02	2.71E-02	2.66E-02	2.67E-02	2.65E-02
6.431	2.38E-02	2.53E-02	2.58E-02	2.60E-02	2.65E-02	2.61E-02	2.64E-02	2.69E-02	2.67E-02	2.64E-02
7.044	2.38E-02	2.64E-02	2.68E-02	2.65E-02	2.69E-02	2.62E-02	2.65E-02	2.73E-02	2.62E-02	2.63E-02
7.656	2.43E-02	2.68E-02	2.69E-02	2.67E-02	2.65E-02	2.61E-02	2.66E-02	2.64E-02	2.63E-02	2.71E-02
8.269	2.42E-02	2.63E-02	2.67E-02	2.63E-02	2.59E-02	2.63E-02	2.67E-02	2.64E-02	2.62E-02	2.66E-02
8.881	2.41E-02	2.57E-02	2.68E-02	2.69E-02	2.64E-02	2.68E-02	2.62E-02	2.66E-02	2.67E-02	2.68E-02
9.494	2.57E-02	2.67E-02	2.65E-02	2.64E-02	2.68E-02	2.70E-02	2.64E-02	2.64E-02	2.67E-02	2.67E-02
10.106	2.66E-02	2.64E-02	2.66E-02	2.61E-02	2.75E-02	2.61E-02	2.62E-02	2.57E-02	2.64E-02	2.65E-02
10.719	3.23E-02	2.73E-02	2.70E-02	2.68E-02	2.63E-02	2.69E-02	2.65E-02	2.69E-02	2.66E-02	2.63E-02
11.331	3.38E-02	2.74E-02	2.63E-02	2.63E-02	2.68E-02	2.71E-02	2.64E-02	2.67E-02	2.63E-02	2.72E-02
11.944	3.50E-02	2.66E-02	2.71E-02	2.65E-02	2.64E-02	2.70E-02	2.67E-02	2.60E-02	2.66E-02	2.73E-02

TRANSMITTED NUMBER FLUX, COSINE CUTOFF= .01000
NORMALIZED TO UNIT INCIDENT NUMBER FLUX

X, H=	.000	6.000	12.000	18.000	30.000	42.000	54.000	66.000	90.000	114.000
.306	2.44E-01	3.87E-01	4.10E-01	3.99E-01	4.28E-01	4.08E-01	4.47E-01	4.13E-01	4.04E-01	4.00E-01
.919	2.59E-01	3.85E-01	4.14E-01	3.98E-01	4.06E-01	4.13E-01	3.97E-01	4.27E-01	4.25E-01	4.25E-01
1.531	3.10E-01	4.07E-01	4.16E-01	4.03E-01	4.11E-01	4.17E-01	3.87E-01	4.14E-01	3.93E-01	4.32E-01
2.144	4.10E-01	4.03E-01	4.12E-01	4.25E-01	3.96E-01	4.08E-01	4.03E-01	3.92E-01	4.02E-01	4.28E-01
2.756	4.59E-01	4.18E-01	4.08E-01	4.05E-01	3.94E-01	4.10E-01	4.03E-01	3.99E-01	4.32E-01	4.17E-01
3.369	4.76E-01	3.95E-01	4.27E-01	4.10E-01	4.01E-01	3.89E-01	4.13E-01	4.05E-01	4.13E-01	4.12E-01
3.981	4.61E-01	4.31E-01	4.16E-01	4.16E-01	4.44E-01	4.09E-01	4.17E-01	3.98E-01	3.88E-01	4.08E-01
4.594	4.70E-01	4.12E-01	3.96E-01	4.05E-01	4.09E-01	4.03E-01	4.13E-01	4.16E-01	4.25E-01	3.84E-01
5.206	5.19E-01	4.24E-01	4.04E-01	4.00E-01	3.98E-01	4.41E-01	4.13E-01	4.19E-01	4.28E-01	4.27E-01
5.819	4.95E-01	4.05E-01	4.06E-01	4.03E-01	4.08E-01	4.05E-01	4.19E-01	4.08E-01	3.99E-01	4.14E-01
6.431	4.93E-01	4.51E-01	4.32E-01	4.21E-01	4.05E-01	4.21E-01	4.12E-01	4.06E-01	4.02E-01	4.17E-01
7.044	4.87E-01	4.08E-01	3.94E-01	4.10E-01	3.98E-01	4.24E-01	4.18E-01	3.79E-01	4.17E-01	4.09E-01
7.656	4.88E-01	4.01E-01	3.95E-01	3.91E-01	4.37E-01	4.37E-01	4.09E-01	4.11E-01	4.04E-01	3.86E-01
8.269	4.88E-01	4.14E-01	3.95E-01	4.23E-01	4.31E-01	4.23E-01	4.16E-01	4.14E-01	4.27E-01	4.17E-01
8.881	4.89E-01	4.26E-01	4.22E-01	4.03E-01	4.15E-01	4.09E-01	4.18E-01	4.03E-01	4.11E-01	4.03E-01
9.494	4.25E-01	4.07E-01	4.21E-01	4.31E-01	3.99E-01	3.92E-01	4.15E-01	4.18E-01	4.37E-01	4.25E-01
10.106	4.30E-01	4.25E-01	4.11E-01	4.31E-01	3.92E-01	4.24E-01	4.17E-01	4.31E-01	4.21E-01	4.18E-01
10.719	2.94E-01	4.08E-01	4.08E-01	4.03E-01	4.26E-01	3.90E-01	4.10E-01	4.00E-01	4.06E-01	4.07E-01
11.331	2.57E-01	3.95E-01	4.19E-01	4.37E-01	4.01E-01	3.92E-01	3.95E-01	4.18E-01	4.06E-01	3.78E-01
11.944	2.58E-01	4.10E-01	4.07E-01	[illegible]E-01	4.12E-01	3.97E-01	3.88E-01	4.41E-01	4.03E-01	4.06E-01

FRACTIONAL STATISTICAL DEVIATION OF RESULTS IN PRECEEDING TABLE

X, H=	.000	6.000	12.000	18.000	30.000	42.000	54.000	66.000	90.000	114.000
.306	4.22E-02	3.26E-02	3.24E-02	3.07E-02	3.21E-02	3.29E-02	3.57E-02	3.24E-02	3.36E-02	3.26E-02
.919	4.50E-02	4.04E-02	3.19E-02	3.36E-02	3.31E-02	3.36E-02	3.36E-02	3.18E-02	3.24E-02	3.27E-02
1.531	5.10E-02	3.10E-02	3.13E-02	3.27E-02	3.58E-02	3.14E-02	3.05E-02	3.36E-02	3.13E-02	3.76E-02
2.144	3.24E-02	3.23E-02	2.94E-02	3.57E-02	2.99E-02	3.28E-02	3.05E-02	3.09E-02	3.68E-02	3.05E-02
2.756	3.20E-02	3.58E-02	3.67E-02	3.36E-02	3.04E-02	3.27E-02	3.27E-02	3.46E-02	4.01E-02	3.15E-02
3.369	2.92E-02	3.31E-02	3.11E-02	3.51E-02	3.07E-02	3.09E-02	3.42E-02	3.29E-02	3.57E-02	3.20E-02
3.981	3.02E-02	3.09E-02	3.07E-02	3.42E-02	3.41E-02	3.20E-02	3.16E-02	3.09E-02	3.09E-02	3.02E-02
4.594	2.83E-02	3.52E-02	3.12E-02	3.29E-02	3.32E-02	3.59E-02	3.23E-02	3.32E-02	3.16E-02	3.04E-02
5.206	3.14E-02	3.18E-02	3.25E-02	3.18E-02	3.04E-02	3.83E-02	3.38E-02	4.13E-02	3.34E-02	3.58E-02
5.819	2.77E-02	3.06E-02	3.32E-02	3.50E-02	3.32E-02	2.96E-02	4.15E-02	3.30E-02	3.24E-02	3.27E-02
6.431	2.32E-02	3.51E-02	3.25E-02	2.98E-02	3.00E-02	3.26E-02	3.37E-02	3.68E-02	3.14E-02	3.22E-02
7.044	2.78E-02	3.35E-02	3.04E-02	3.33E-02	3.44E-02	3.29E-02	3.95E-02	3.15E-02	3.26E-02	3.15E-02
7.656	3.07E-02	3.50E-02	3.20E-02	3.14E-02	3.92E-02	3.52E-02	3.16E-02	3.44E-02	3.14E-02	3.32E-02
8.269	3.25E-02	3.35E-02	3.23E-02	3.09E-02	3.32E-02	3.97E-02	3.46E-02	3.21E-02	3.49E-02	3.49E-02
8.881	2.91E-02	3.10E-02	3.91E-02	3.36E-02	3.12E-02	3.66E-02	3.30E-02	3.08E-02	3.45E-02	3.12E-02
9.494	2.94E-02	3.41E-02	3.50E-02	3.53E-02	3.56E-02	3.14E-02	3.12E-02	3.25E-02	3.27E-02	4.05E-02
10.106	3.96E-02	3.42E-02	3.09E-02	3.46E-02	4.17E-02	3.14E-02	3.44E-02	3.10E-02	3.42E-02	3.29E-02
10.719	3.95E-02	3.37E-02	3.91E-02	3.26E-02	3.45E-02	3.10E-02	3.27E-02	3.19E-02	3.63E-02	3.02E-02
11.331	3.94E-02	3.57E-02	3.61E-02	3.86E-02	3.28E-02	3.22E-02	2.93E-02	3.78E-02	2.95E-02	3.05E-02
11.944	4.86E-02	3.06E-02	3.99E-02	3.38E-02	3.17E-02	3.40E-02	3.01E-02	3.46E-02	3.22E-02	4.27E-02

EXPOSURE DUE TO TRANSMITTED SCATTERED RADIATION, COSINE CUTOFF= .01000
NORMALIZED TO UNIT EXPOSURE DUE TO INCIDENT RADIATION

X, H=	.000	6.000	12.000	18.000	30.000	42.000	54.000	66.000	90.000	114.000
.306	1.03E-01	1.75E-01	1.88E-01	1.78E-01	1.91E-01	1.81E-01	1.93E-01	1.86E-01	1.78E-01	1.81E-01
.919	1.11E-01	1.68E-01	1.79E-01	1.75E-01	1.78E-01	1.88E-01	1.81E-01	1.92E-01	1.90E-01	1.88E-01
1.531	1.31E-01	1.81E-01	1.81E-01	1.78E-01	1.81E-01	1.89E-01	1.72E-01	1.85E-01	1.77E-01	1.97E-01
2.144	1.77E-01	1.75E-01	1.89E-01	1.88E-01	1.85E-01	1.77E-01	1.85E-01	1.84E-01	1.75E-01	1.95E-01
2.756	2.10E-01	1.87E-01	1.79E-01	1.80E-01	1.82E-01	1.87E-01	1.79E-01	1.81E-01	1.88E-01	1.86E-01
3.369	2.18E-01	1.77E-01	1.90E-01	1.86E-01	1.83E-01	1.79E-01	1.81E-01	1.81E-01	1.79E-01	1.85E-01
3.981	2.06E-01	2.01E-01	1.89E-01	1.81E-01	1.95E-01	1.83E-01	1.85E-01	1.77E-01	1.82E-01	1.82E-01
4.594	2.16E-01	1.89E-01	1.81E-01	1.85E-01	1.80E-01	1.81E-01	1.83E-01	1.84E-01	1.84E-01	1.76E-01
5.206	2.32E-01	1.84E-01	1.77E-01	1.84E-01	1.78E-01	1.88E-01	1.88E-01	1.80E-01	1.90E-01	1.83E-01
5.819	2.25E-01	1.88E-01	1.88E-01	1.76E-01	1.86E-01	1.90E-01	1.83E-01	1.85E-01	1.83E-01	1.88E-01
6.431	2.31E-01	2.09E-01	1.95E-01	2.00E-01	1.78E-01	1.93E-01	1.87E-01	1.81E-01	1.83E-01	1.88E-01
7.044	2.26E-01	1.89E-01	1.81E-01	1.85E-01	1.83E-01	1.91E-01	1.83E-01	1.71E-01	1.88E-01	1.77E-01
7.656	2.19E-01	1.83E-01	1.81E-01	1.78E-01	1.88E-01	1.90E-01	1.79E-01	1.91E-01	1.83E-01	1.81E-01
8.269	2.17E-01	1.94E-01	1.83E-01	1.91E-01	1.93E-01	1.89E-01	1.83E-01	1.86E-01	1.87E-01	1.82E-01
8.881	2.24E-01	1.92E-01	1.85E-01	1.78E-01	1.85E-01	1.76E-01	1.87E-01	1.75E-01	1.83E-01	1.82E-01
9.494	1.93E-01	1.79E-01	1.86E-01	1.85E-01	1.78E-01	1.77E-01	1.88E-01	1.82E-01	1.82E-01	1.82E-01
10.106	1.84E-01	1.81E-01	1.80E-01	1.93E-01	1.72E-01	1.88E-01	1.87E-01	1.92E-01	1.92E-01	1.82E-01
10.719	1.31E-01	1.76E-01	1.78E-01	1.72E-01	1.84E-01	1.79E-01	1.87E-01	1.80E-01	1.80E-01	1.86E-01
11.331	1.37E-01	1.68E-01	1.86E-01	1.90E-01	1.79E-01	1.78E-01	1.81E-01	1.84E-01	1.88E-01	1.73E-01
11.944	1.09E-01	1.76E-01	1.77E-01	1.88E-01	1.91E-01	1.69E-01	1.80E-01	1.94E-01	1.80E-01	1.77E-01

FRACTICNAL STATISTICAL DEVIATION OF RESULTS IN PRECEEDING TABLE

X, H=	.000	6.000	12.000	18.000	30.000	42.000	54.000	66.000	90.000	114.000
.306	4.19E-02	3.33E-02	3.22E-02	3.22E-02	3.18E-02	3.25E-02	3.60E-02	3.21E-02	3.35E-02	3.24E-02
.919	4.19E-02	3.33E-02	3.22E-02	3.32E-02	3.24E-02	3.22E-02	3.26E-02	3.19E-02	3.17E-02	3.20E-02
1.531	3.84E-02	3.22E-02	3.15E-02	3.26E-02	3.33E-02	3.16E-02	3.25E-02	3.24E-02	3.18E-02	3.54E-02
2.144	3.28E-02	3.24E-02	3.14E-02	3.61E-02	3.18E-02	3.23E-02	3.10E-02	3.20E-02	3.28E-02	3.09E-02
2.756	3.34E-02	3.21E-02	3.40E-02	3.26E-02	3.16E-02	3.20E-02	3.33E-02	3.28E-02	3.20E-02	3.16E-02
3.369	2.96E-02	3.26E-02	3.15E-02	3.13E-02	3.15E-02	3.19E-02	3.25E-02	3.22E-02	3.32E-02	3.18E-02
3.981	2.95E-02	3.06E-02	3.09E-02	3.18E-02	3.08E-02	3.17E-02	3.14E-02	3.22E-02	3.18E-02	3.21E-02
4.594	2.96E-02	3.16E-02	3.15E-02	3.26E-02	3.19E-02	3.47E-02	3.26E-02	3.25E-02	3.22E-02	3.22E-02
5.206	2.89E-02	3.16E-02	3.25E-02	3.19E-02	3.19E-02	3.64E-02	3.26E-02	3.24E-02	3.18E-02	3.21E-02
5.819	2.87E-02	3.16E-02	3.16E-02	3.24E-02	3.28E-02	3.12E-02	3.34E-02	3.19E-02	3.20E-02	3.13E-02
6.431	2.88E-02	3.45E-02	3.24E-02	3.12E-02	3.18E-02	3.25E-02	3.24E-02	3.31E-02	3.21E-02	3.16E-02
7.044	2.88E-02	3.19E-02	3.15E-02	3.24E-02	3.31E-02	3.11E-02	3.21E-02	3.30E-02	3.12E-02	3.30E-02
7.656	2.93E-02	3.29E-02	3.23E-02	3.31E-02	3.21E-02	3.19E-02	3.20E-02	3.57E-02	3.15E-02	3.21E-02
8.269	2.90E-02	3.24E-02	3.29E-02	3.15E-02	3.21E-02	3.25E-02	3.34E-02	3.26E-02	3.17E-02	3.27E-02
8.881	2.89E-02	3.10E-02	3.34E-02	3.19E-02	3.24E-02	3.22E-02	3.13E-02	3.18E-02	3.42E-02	3.23E-02
9.494	3.07E-02	3.32E-02	3.22E-02	3.24E-02	3.67E-02	3.25E-02	3.16E-02	3.20E-02	3.21E-02	3.47E-02
10.106	3.39E-02	3.17E-02	3.20E-02	3.22E-02	3.34E-02	3.18E-02	3.18E-02	3.13E-02	3.27E-02	3.27E-02
10.719	3.98E-02	3.26E-02	3.83E-02	3.29E-02	3.26E-02	3.17E-02	3.18E-02	3.21E-02	3.70E-02	3.15E-02
11.331	4.07E-02	3.44E-02	3.13E-02	3.12E-02	3.24E-02	3.26E-02	3.13E-02	3.29E-02	3.11E-02	3.22E-02
11.944	4.43E-02	3.22E-02	3.27E-02	3.26E-02	3.20E-02	3.27E-02	3.22E-02	3.11E-02	3.20E-02	3.32E-02

EXPOSURE DUE TO UNSCATTERED RADIATION
NORMALIZED TO UNIT EXPOSURE DUE TO INCIDENT RADIATION

X, H=	.000	6.000	12.000	18.000	30.000	42.000	54.000	66.000	90.000	114.000
.306	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02
.919	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02
1.531	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02
2.144	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01
2.756	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01
3.369	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01
3.981	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01
4.594	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01
5.206	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01
5.819	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01
6.431	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01
7.044	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01
7.656	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01
8.269	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01
8.881	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01
9.494	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01
10.106	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01	2.46E-01
10.719	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02
11.331	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02
11.944	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02	3.07E-02

EXPOSURE (SCATTERED PLUS UNSCATTERED), COSINE CUTOFF= .01000
NORMALIZED TO UNIT EXPOSURE DUE TO INCIDENT RADIATION

X, H=	.000	6.000	12.000	18.000	30.000	42.000	54.000	66.000	90.000	114.000
.306	1.34E-01	2.06E-01	2.19E-01	2.08E-01	2.22E-01	2.11E-01	2.24E-01	2.17E-01	2.08E-01	2.11E-01
.919	1.42E-01	1.99E-01	2.09E-01	2.06E-01	2.08E-01	2.18E-01	2.11E-01	2.22E-01	2.21E-01	2.19E-01
1.531	1.62E-01	2.12E-01	2.11E-01	2.08E-01	2.12E-01	2.20E-01	2.03E-01	2.16E-01	2.08E-01	2.28E-01
2.144	4.23E-01	4.21E-01	4.35E-01	4.34E-01	4.31E-01	4.23E-01	4.31E-01	4.30E-01	4.21E-01	4.41E-01
2.756	4.56E-01	4.33E-01	4.25E-01	4.26E-01	4.28E-01	4.33E-01	4.25E-01	4.27E-01	4.34E-01	4.32E-01
3.369	4.64E-01	4.23E-01	4.36E-01	4.32E-01	4.29E-01	4.25E-01	4.27E-01	4.27E-01	4.25E-01	4.31E-01
3.981	4.52E-01	4.47E-01	4.35E-01	4.27E-01	4.41E-01	4.29E-01	4.31E-01	4.23E-01	4.28E-01	4.28E-01
4.594	4.62E-01	4.35E-01	4.27E-01	4.31E-01	4.26E-01	4.27E-01	4.29E-01	4.30E-01	4.30E-01	4.22E-01
5.206	4.78E-01	4.30E-01	4.23E-01	4.30E-01	4.24E-01	4.34E-01	4.34E-01	4.26E-01	4.36E-01	4.29E-01
5.819	4.71E-01	4.34E-01	4.34E-01	4.22E-01	4.32E-01	4.36E-01	4.29E-01	4.31E-01	4.29E-01	4.34E-01
6.431	4.77E-01	4.55E-01	4.41E-01	4.46E-01	4.25E-01	4.39E-01	4.33E-01	4.27E-01	4.29E-01	4.34E-01
7.044	4.72E-01	4.35E-01	4.27E-01	4.31E-01	4.29E-01	4.37E-01	4.29E-01	4.17E-01	4.34E-01	4.23E-01
7.656	4.65E-01	4.29E-01	4.27E-01	4.24E-01	4.34E-01	4.36E-01	4.25E-01	4.37E-01	4.29E-01	4.27E-01
8.269	4.63E-01	4.40E-01	4.29E-01	4.38E-01	4.39E-01	4.35E-01	4.29E-01	4.32E-01	4.33E-01	4.29E-01
8.881	4.70E-01	4.38E-01	4.31E-01	4.24E-01	4.31E-01	4.22E-01	4.33E-01	4.21E-01	4.29E-01	4.28E-01
9.494	4.39E-01	4.25E-01	4.32E-01	4.31E-01	4.24E-01	4.23E-01	4.34E-01	4.29E-01	4.28E-01	4.29E-01
10.106	4.30E-01	4.27E-01	4.26E-01	4.39E-01	4.18E-01	4.34E-01	4.33E-01	4.38E-01	4.38E-01	4.28E-01
10.719	1.62E-01	2.06E-01	2.09E-01	2.02E-01	2.15E-01	2.09E-01	2.18E-01	2.10E-01	2.11E-01	2.17E-01
11.331	1.39E-01	1.98E-01	2.16E-01	2.21E-01	2.10E-01	2.09E-01	2.11E-01	2.15E-01	2.19E-01	2.03E-01
11.944	1.40E-01	2.07E-01	2.07E-01	2.18E-01	2.22E-01	1.99E-01	2.11E-01	2.25E-01	2.11E-01	2.08E-01

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* University of Illinois Urbana, Illinois	2a. REPORT SECURITY CLASSIFICATION Unclassified
	2b. GROUP

3. REPORT TITLE

MONTE CARLO CALCULATION OF GAMMA-RAY PENETRATION OF RIBBED SLABS

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
Final

5. AUTHOR(S) *(First name, middle initial, last name)*

Edgar E. Morris

6. REPORT DATE December, 1968	7a. TOTAL NO. OF PAGES 86	7b. NO. OF REFS 6

8a. CONTRACT OR GRANT NO. N0022866C0311	9a. ORIGINATOR'S REPORT NUMBER(S) Nuclear Radiation Shielding Studies Report No. 8
b. PROJECT NO. OCD Work Unit 1112C	
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)* NRSS 8; NRDL TRC-68-53
d.	

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Office of Civil Defense Department of the Army Washington, D. C.

13. ABSTRACT

Radiation, gamma rays, slabs, Monte Carlo, shielding

Data are given in the form of attenuation factors for the exposure due to gamma radiation transmitted by a ribbed slab. The ribbed slab is made of concrete and is similar to one which has been used in experimental studies conducted at the University of Illinois. The source radiation was assumed to be that of Co-60 with source spectrum degradation due to the self-shielding of the source. Four angles of incidence, 0°, 45°, 60°, and 75°, were considered. In addition, the effect of a beam of radiation incident with directions diverging 2.5° on either side of 45° was studied in a rather crude fashion. Attenuation factors for 1.25 MeV gamma radiation incident normally on a simulated wood floor are included in an appendix.

DD FORM 1 NOV 65 1473 (PAGE 1)

S/N 0101-807-6801

UNCLASSIFIED
Security Classification

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Radiation						
Gamma Rays						
Slabs						
Monte Carlo						
Shielding						

DD FORM 1 NOV 65 1473 (BACK)
(PAGE 2)

Security Classification